VOLUME V OCTOBER, 1940 NUMBER 4

GEOPHYSICS

A Journal of General and Applied Geophysics

TIDAL FORCE OBSERVATIONS*

ALFRED WOLF†

ABSTRACT

Observations of the tidal variation of gravity at Tulsa, Oklahoma, are presented for the period December 10 to December 16, 1939. A good correlation is found between observed and calculated values with the factor $(1+h-3k/2)=1.2$.

During the past few years, a great deal of progress has been made in the design of commercial gravimeters for geophysical exploration work. These instruments have now reached a state of great perfection; their accuracy in the field is of the order of a few parts in a hundred million of the value of gravity. With such gravimeters, it becomes possible to obtain a record of the variation of gravity due to tidal forces of the Sun and of the Moon.

The data presented here were obtained during a laboratory test of a LaCoste-Romberg gravimeter. The test was made primarily to check the drift of the instrument, but the data recorded give a clear picture of tidal gravity variation which is thought to be of interest to those working in this field.

The LaCoste-Romberg gravimeter is of the astatic type. It is quite insensitive to levelling errors and is compensated for atmospheric pressure variations. The temperature of the instrument is thermostatically controlled to within 0.02°C. The calibration, linear over the entire range of the instrument, was supplied by the makers.

In the course of these tests, the ambient temperature was purposely varied over a wide range. No correlation was found between ambient temperature and instrument readings. The data are therefore believed to be free from temperature effects.

* Original manuscript submitted July, 1940.

† Geophysical Research Corporation, Tulsa, Oklahoma.

The instrument was set up in the Laboratory of the Geophysical Research Corporation at Tulsa, Oklahoma (Latitude 36.2° N, Longitude 96° W), and readings were taken at ten minute intervals during the period December 10 to December 16, 1939. A chart of the results obtained is reproduced in Figs. 1a, 1b, 1c. All gravity values are given in milligals; the time shown is Greenwich Civil Time. The New Moon phase occurs December 10 at $21^h\ 45^m$ G.C.T.

Curve A shows instrument readings at twenty minute intervals. No correction was applied to the observed values. The instrument readings were merely multiplied by the calibration constant to convert them into milligals.

Curve B in Fig. 1 is the gravimeter drift curve. This curve was obtained by calculating the twenty-four hour running averages of instrument readings, and extrapolating the resulting curve for twelve hours at the beginning and at the end of the chart.

The observed tidal gravity variation is shown by Curve C, obtained by correcting instrument readings for drift. Two factors limit the accuracy of this curve. One is the error made in reading the instrument, which is between 0.01 and 0.02 milligals. A more serious

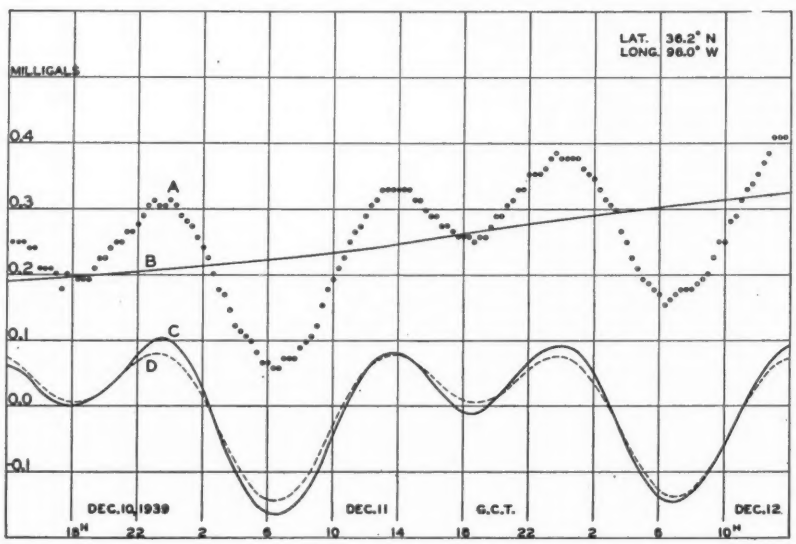


FIG. 1a. Tidal Gravity Variation. A—Gravity Meter Readings. B—Drift Curve. C—Observed Gravity Variation. D—Calculated Gravity Variation.

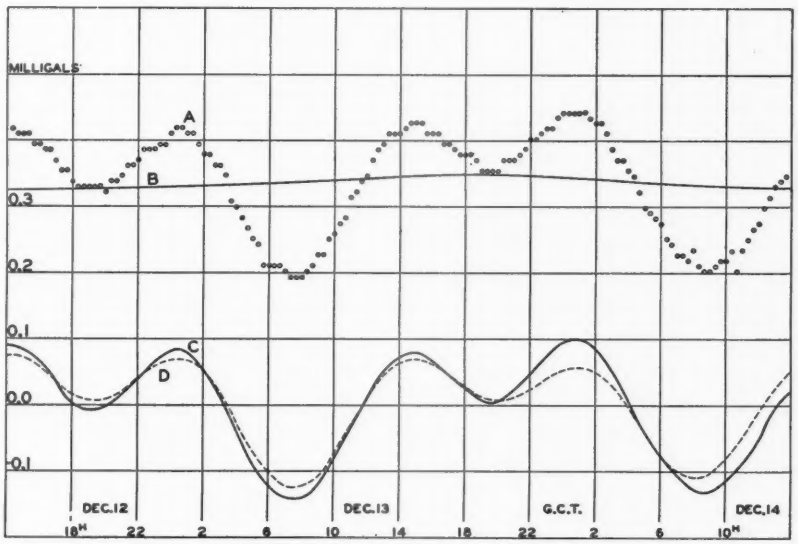


FIG. 1b. Tidal Gravity Variation.

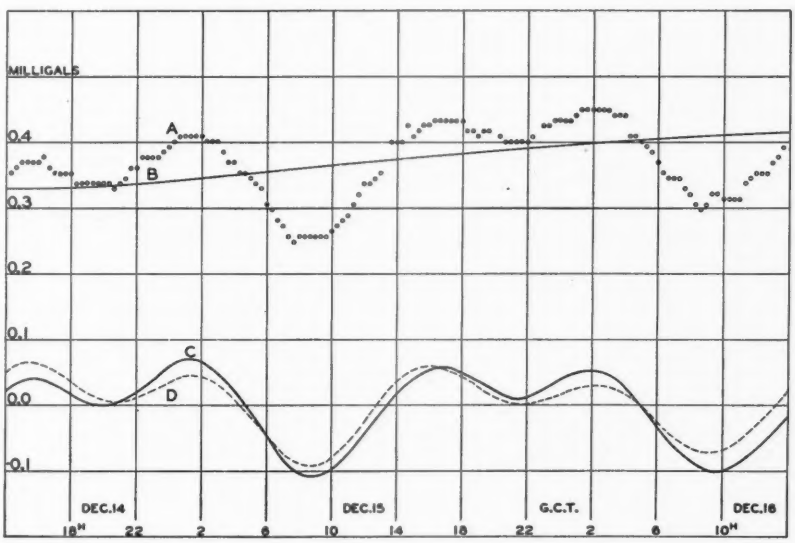


FIG. 1c. Tidal Gravity Variation.

limitation of the accuracy is to be found in instrumental drift which cannot be wholly corrected by subtracting twenty-four hour running averages.

The broken line, Curve D, represents the theoretical tidal gravity variation for an unyielding Earth. This computed variation would be the true gravity variation in the absence of Earth tides and of ocean tides. The calculation was made from the undeveloped form of the tidal potential of the Sun and of the Moon.

Because of the slight change of shape of the Earth under the influence of the tidal forces, the observed gravity variations should differ somewhat from values calculated for an unyielding Earth. According to simple theory, the observed and the calculated gravity variation should be approximately in phase; the amplitude of the observed variation should be greater by the constant factor

$$1 + h - 3k/2 \qquad (1)$$

where h, k are two numbers defined by A. E. H. Love.[1]

A comparison of the observed and calculated gravity variation curves in the chart shows only very small phase differences in the first half of the record; in the second half, phase differences up to 40 minutes occur. The value of the factor (1) can be computed by comparing the maximum variation of gravity for successive cycles of the observed and of the calculated curves, C and D. It was found that the best value of (1) obtained in this way is

$$1 + h - 3k/2 = 1.2 \qquad (2)$$

This is an average value, the individual factors range from 1.0 to 1.5.

The observations presented here were initiated by Mr. W. T. Born, and were made under the direction of Mr. J. M. Kendall.

[1] Love: Proc. Roy. Soc. 82; cf. also Jeffreys: The Earth, 2nd Ed., p. 233.

THE RELIABILITY OF GEOPHYSICAL ANOMALIES ON THE BASIS OF PROBABILITY CONSIDERATIONS*

THOMAS A. ELKINS†

ABSTRACT

When data are used which contain random errors, there is always some question as to whether a supposed anomaly may not be real but due only to errors in the data. This paper describes a method of testing this point, which is worked out in detail assuming the Gaussian error law for the case of independent values. Possible applications of the method to the problems of contouring data, and evaluating and ranking anomalies are suggested. Examples of the use of the method on gravity and soil gas analysis data are also given.

INTRODUCTION

When a "weak" geophysical anomaly is being studied, the question arises as to whether the anomaly is real or due only to an accidental arrangement of errors in the data. Such a question is relevant enough for gravity, magnetic, and the other classic types of data but is inescapable for such modern techniques as soil or soil gas analysis. In these the magnitude of the quantities measured approaches the vanishingly small and consequently—and this is the important point—the measured quantities may be of the order of the total experimental error, which includes not merely instrumental or analytical errors but also errors due to random variations in the environment of the samples or measuring points.

The method discussed in this paper enables one to give a numerical answer to this question of reliability of an anomaly. It is assumed that the theoretical distribution of the random errors in the data is known. The basic principle of the method is this: we tentatively assume that the anomaly is merely a collection of random errors; we then compute the probability that a collection of such errors (or of errors of greater magnitude in absolute value) will occur; if this probability is large, we say that the anomaly is probably due to errors; if it is small, we consider that it is unlikely that the anomaly is due to errors and we decide consequently that the anomaly is reliable. We shall repeat the statement of the basic principle, because in the remainder of the paper

* Presented at the Annual Meeting, Chicago, April 11, 1940.

† Gulf Research & Development Company, Pittsburgh, Pa.

it is applied time and time again and it is important to keep it clearly in mind: we assume that the anomaly is made up of errors; if the probability we compute is large, we say that the anomaly is probably due to errors; if it is small, we say that the anomaly is reliable. In statistical language, we are applying a test of significance to the anomaly. The question that arises immediately is: what limiting probability shall we set as a dividing line between large and small probabilities, that is, between errors and "real" anomalies?

THE LIMITING PROBABILITY

To discuss this question it will be advisable to state the problem in more specific terms. Let us suppose that we have a contour map of some variety of data taken at discrete points. Suppose further that the values at the different points are independent and that all readings follow the same Gaussian error law with known probable error, E, or known standard deviation,[1] σ.

Our problem is essentially that of making an observation with a precise measuring instrument, an observation so minute that it approaches the "noise level" of the instrument or of the environment in which the measurement is made. Setting the limiting probability amounts to answering the question: for a single observation to be reliable, how many times the noise level must it be? There is no definite answer, for the answer depends upon the degree of certainty desired. For example, the probability of a random error greater in absolute value than twice the standard deviation is about one twentieth. Otherwise stated, the odds are about nineteen to one that a value 2σ is "real" and not an accidental spurt in the noise level.

This noise level problem appears to have been investigated more thoroughly for the Brownian motion of galvanometers than for any other case. Barnes and Silverman in their discussion of the question[2] assume from experimental experience that the smallest significant galvanometer deflection is four times the standard deviation due to the Brownian motion. The probability of an error greater in absolute

[1] In the theory of errors the standard deviation is usually called the mean square error. In statistical work "standard deviation" is the more common name and we shall use it in preference to the other. For the Gaussian error law, E and σ are connected by the well known relation $E=0.6745\sigma$.

[2] See pages 176–177 of R. Bowling Barnes and S. Silverman, "Brownian Motion as a Natural Limit to all Measuring Processes," Reviews of Modern Physics, 6, 162–192 (1934).

value than four times the standard deviation is about 0.00006. This limiting probability for 4σ is the value we adopt for the examples of the use of the method which we shall give later on.

If we think that this criterion is too stringent, we might adopt a limiting value of three times the standard deviation, for which the corresponding probability is about 0.00270. This is a common limit in statistical work, in which the question is usually considered from the opposite view-point; that is, an observation which lies within the range of three times the standard deviation from the mean is considered normal, an observation outside this range is rejected or at least requires explanation.

DESCRIPTION OF THE METHOD

Let us see how we should use a criterion of this nature, taking that for four times the standard deviation for the sake of definiteness. We thus set our limiting probability at about 0.00006. If the computed probability for the values making up an anomaly is greater than this value, we discard it as being probably due to errors, if the probability is less than this value, we regard the anomaly as reliable.

First, we discard all single station anomalies less than or equal in absolute value to 4σ. (We might discard all the other single station anomalies too, since we always doubt the reality of such anomalies, but that is outside the present line of argument.) Next, consider anomalies based on two stations: The values at the two stations are both positive or both negative. Let k be the probability of the occurrence of an error equal to or greater than c, where c is positive. Then, if we assume that the errors in the two stations are independent, the probability of the occurrence of two errors of the same sign (both positive or both negative) equal to or greater than c in absolute value equals $2k^2$. We then set $2k^2$ equal to our limiting probability (which is about 0.00006) and find that c is about 2.5σ, which is therefore the limiting value for the stations of a two station anomaly. We then discard all two station anomalies for which both stations have values less than or equal in absolute value to 2.5σ. To find the limiting value for n stations we set $2k^n$ equal to the limiting probability and thus obtain the values in Table 1. These values are the smallest absolute values which each station of a many-station anomaly may have and still be reliable, on the basis of the limiting probability chosen. Anomalies with all absolute values smaller are discarded as unreliable. The smallest reliable values have also been listed for a limiting probability

for 3σ. For convenience in use we also give the equivalent values in terms of the probable error, E. All the values are computed to only one decimal place, which should be sufficient in practice.

For a number of stations greater than fourteen when the limiting probability is that for 4σ the smallest reliable value is zero or perhaps more accurately, some very small positive (or negative) number. The same statement holds for a number of stations greater than nine when the limiting probability is that for 3σ. That is, the reliability of an

TABLE 1

VALUE OF SMALLEST RELIABLE ANOMALY

No. of Stations Supporting Anomaly	*Limiting Probability is for*			
	4σ (*about 0.00006*)		3σ (*about 0.00270*)	
1	4σ	5.9E	3σ	4.4E
2	2.5σ	3.8E	1.8σ	2.7E
3	1.9σ	2.8E	1.2σ	1.8E
4	1.4σ	2.1E	0.9σ	1.3E
5	1.1σ	1.7E	0.6σ	0.9E
6	0.9σ	1.4E	0.4σ	0.6E
7	0.7σ	1.1E	0.3σ	0.4E
8	0.6σ	0.9E	0.2σ	0.2E
9	0.5σ	0.7E	0.1σ	0.1E
10	0.4σ	0.6E		
11	0.3σ	0.4E		
12	0.2σ	0.3E		
13	0.1σ	0.2E		
14	0.1σ	0.1E		

anomaly is indicated for such cases merely by the fact that the signs of the values are all the same, without regard to the magnitude of the values. This may seem surprising at first but it may be checked by the following simple calculation. The probability of occurrence of a positive error is $1/2$. Therefore the probability of the occurrence of n errors of the same sign is $2/2^n$. For n greater than 14 the value of this probability is less than the limiting probability for 4σ (about 0.00006), which fact explains the paradox.

It is evident that some cases will arise which are not included in Table 1. For example, suppose that we have an anomaly based on two independent observations, 1.8σ and 3σ. The probability of an error 1.8σ or greater is about 0.03593, 3σ or greater about 0.00135. The

probability of the occurrence of two errors of the same sign, one equal to or greater in absolute value than 1.8σ, the other equal to or greater in absolute value than 3σ, is then twice the product of the probabilities just given. The probability is therefore about 0.00010. If we are using the limiting probability for 4σ (about 0.00006), we must say that the anomaly in question is too small to be reliable; for the probability of its being due to errors is greater than the limiting probability. A similar process will handle any other case which may arise.[3]

A SHORT CUT APPROXIMATION

As a first approximation in such cases the average of the observations might be used. For the case just mentioned the average would be 2.4σ, which from the table above is too small (for two stations) to be reliable. The actual probability for the occurrence of two errors of the same sign each 2.4σ or greater in absolute value is about 0.00013, which is somewhat greater than the true value for the case mentioned above, which was found to be about 0.00010. In fact we can prove[4] that this averaging method will always give "conservative" results, that is, the probability value computed by this method will be greater than the correct value. The averaging method will therefore sometimes cause a reliable anomaly to be discarded as unreliable when it should not but it will never indicate falsely that an unreliable anomaly is "real." In critical cases it will probably be necessary to use the longer but more accurate method described above.

We thus see that if we adopt a limiting value of probability, this process of eliminating anomalies made up of random errors is quite straightforward.[5]

[3] The use of already published tables makes such computations fairly easy. If the standard deviation is the unit, the table on page 533 of G. Udny Yule and M. G. Kendall, "An Introduction to the Theory of Statistics," 11th edition, London: Charles Griffin & Company, Ltd., 1937, may be used. If the probable error is the unit, Table 25 on page 57 of "Smithsonian Physical Tables" (prepared by Frederick E. Fowle), 2nd reprint of 7th edition, Washington: Smithsonian Institution, 1923, may be used.

[4] Since the proof is rather long, it is given in the Appendix.

[5] We have assumed throughout that the error law is the Gaussian normal error law and that σ is the same for all readings. It is obvious that the method also applies for the slightly more general case in which σ is not constant and that the method may be extended to more general error laws. This latter extension would probably be only of theoretical interest, since physical quantities are usually determined under conditions such that the normal error law is a sufficiently close approximation.

PRACTICAL APPLICATIONS OF THE PRECEDING IDEAS

We shall now discuss some of the possible uses of the theory.

(1) *Choice of Contour Interval*

In many cases the contour interval used for geophysical data is dictated principally by considerations of ease of drawing; that is, the contour interval is chosen larger than it should be if maximum detail were sought. When the magnitude of the anomalies is sufficiently large, such a choice will make no particular difference; the discussion following is directed towards the case in which it is sought to make the contour interval as small as is reasonable.

There is a semi-empirical method of determining the contour interval for data containing random errors. This is to contour the data to successively smaller contour intervals. The presence of random errors should be indicated by "wiggles" of increasing size. The best contour interval would be the smallest interval which does not yet show "wiggles" large enough to be mistaken for real variations or deviations. This is hardly a definite criterion since it will vary with the contourer. It is the experience of the writer that this view-point leads in practice to the conclusion that a contour interval equal to the probable error is a limiting one or even smaller than the limiting one.

We shall now use the reliability theory to derive a criterion which a suitable contour interval should satisfy. This is a demand that closed contour anomalies have a high probability of being "real." The best contour interval on that basis will depend on the limiting probability set and on the number of points required to define the closure. For example, suppose we adopt the limiting probability for 4σ (about 0.00006). Referring to Table 1 we see that even if as many as eight points define the closure, the smallest reliable value is nine-tenths of the probable error. With a reasonable spacing of data anything defined by more than eight points certainly should be perceptible from the area covered or from the numerical values alone. From this new view-point a contour interval equal to the probable error again seems to be a minimum one in conformity with the result from the use of the semi-empirical criterion mentioned in the previous paragraph. In fact, when one considers that the chief importance of closures is that they give a visual indication of features due to only a few points which might otherwise be missed at a rough inspection, a minimum contour interval equal to twice the probable error or even greater is reasonable, as is evident from the limiting values given for four and five station anomalies in Table 1.

(2) *Elimination of Minor Anomalies*

It is important here to note that in judging the reliability of anomalies by probability considerations, it may be necessary to remove a "regional" or reduce the values from some arbitrary datum, since otherwise it would be meaningless to consider the magnitudes as random errors. Then the processes described earlier in the paper can be applied to test the reliability of the minor anomalies which result. As a result of the tests those which are judged unreliable may be eliminated. It must be remembered that since we are working on a basis of probability, we should expect occasionally to call an anomaly "real" when it is actually spurious and vice versa.

(3) *Ranking and Evaluating Major Anomalies*

In an area which contains numerous anomalies all of which are reliable it is sometimes desirable to rank them in order of importance. The probability considerations discussed in this paper enable us to compute the probability that an anomaly is merely an accidental combination of random errors. A reasonable ranking, in order of increasing importance, would then be that according to decreasing probability values.

EXAMPLES OF THE USE OF THE METHOD

Three examples will now be presented of the use of the method on practical data, utilizing the averaging approximation.

(1) *A Gravity Survey in the Texas Gulf Coast*

Fig. 1 shows pendulum data and the corresponding gravity contours over a portion of the Texas Gulf Coast. The pendulum data were taken by a Gulf Research & Development Company troop early in this type of work before the final development of the apparatus. The probable error for these data was estimated at 0.35 mg. The gravity values are residual values after the subtraction of a smooth regional.

Fig. 2 shows the gravity contours after unreliable anomalies have been removed and the contours smoothed somewhat, especially to reduce the roughness caused by the omissions.

We can check the reliability method for this case because the same area has been resurveyed with the gravimeter by a Gulf Research & Development Company troop. The probable error for the gravimeter data is much less than for the pendulum data. The residual gravity contours based on the gravimeter data are shown on Fig. 3. The

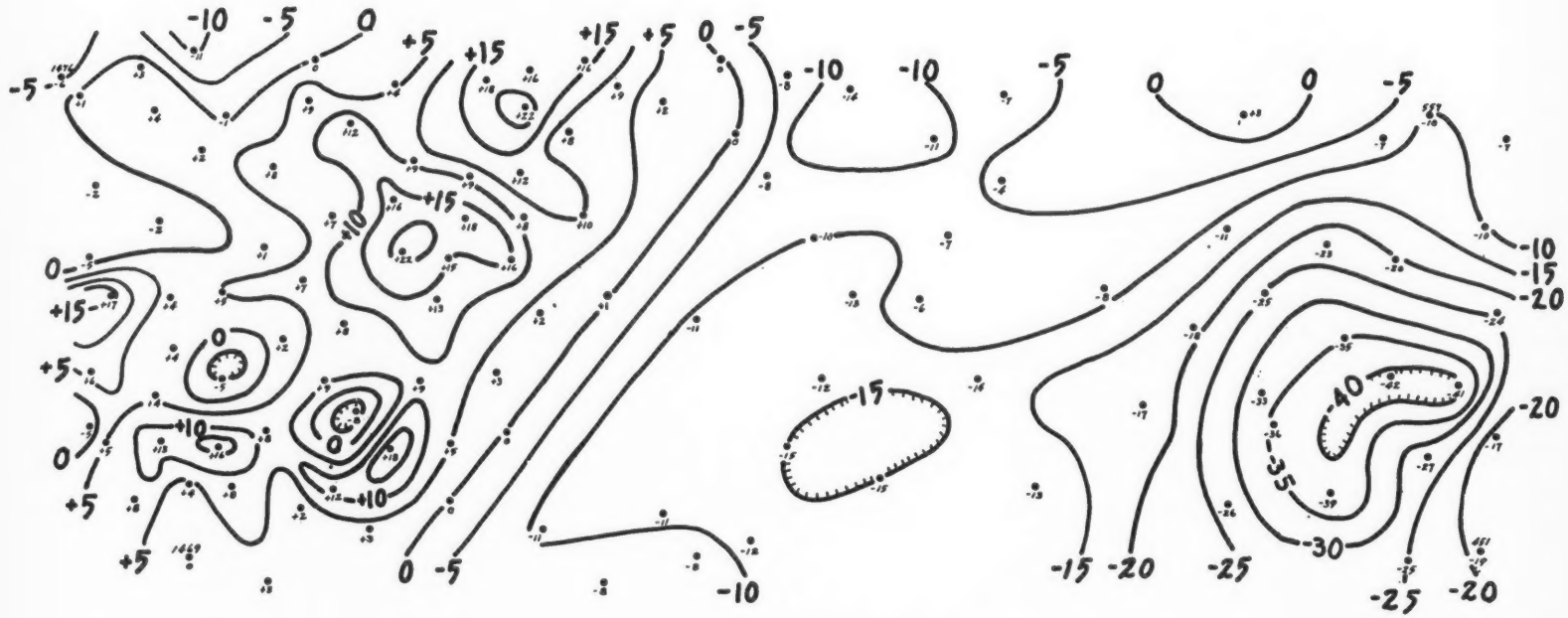


FIG. 1. Residual gravity over a portion of Texas Gulf Coast—pendulum data. Gravity values are in 0.1 milligal units. Contour interval is 0.5 milligal.

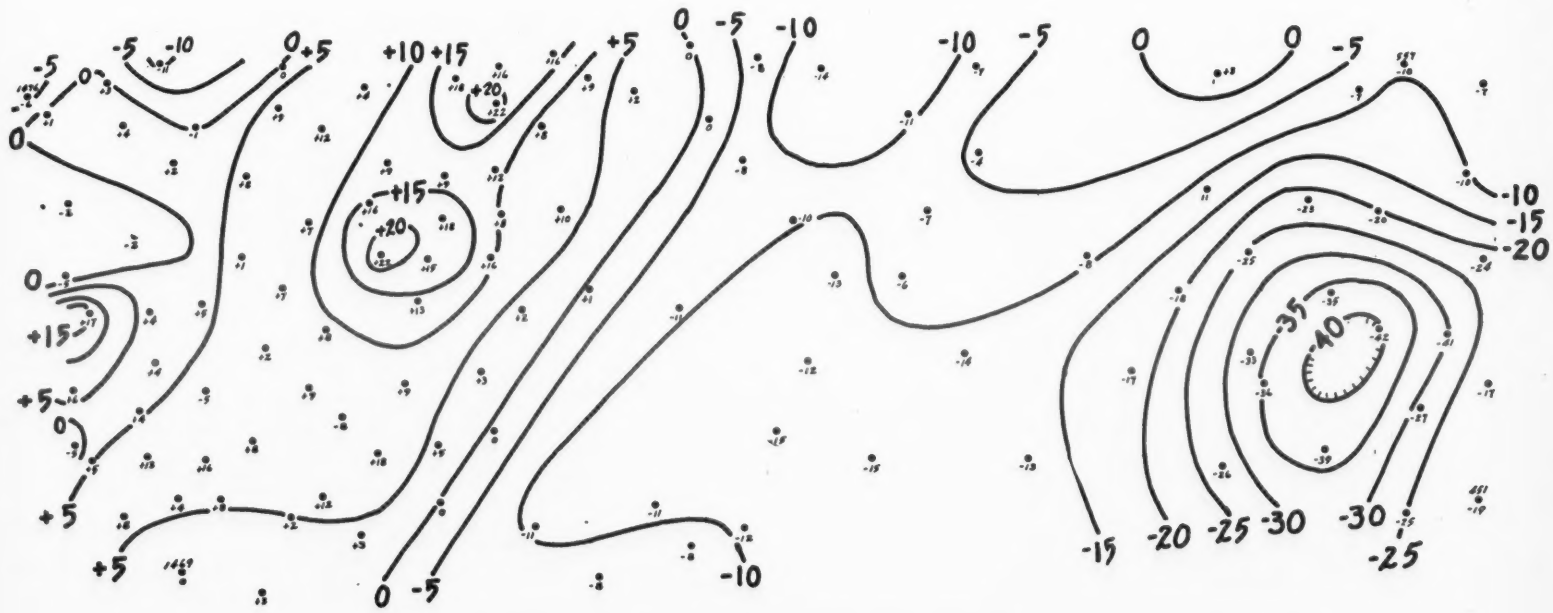


FIG. 2. Residual gravity over a portion of Texas Gulf Coast—pendulum data with unreliable anomalies disregarded in contouring. Gravity values are in 0.1 milligal units. Contour interval is 0.5 milligal.

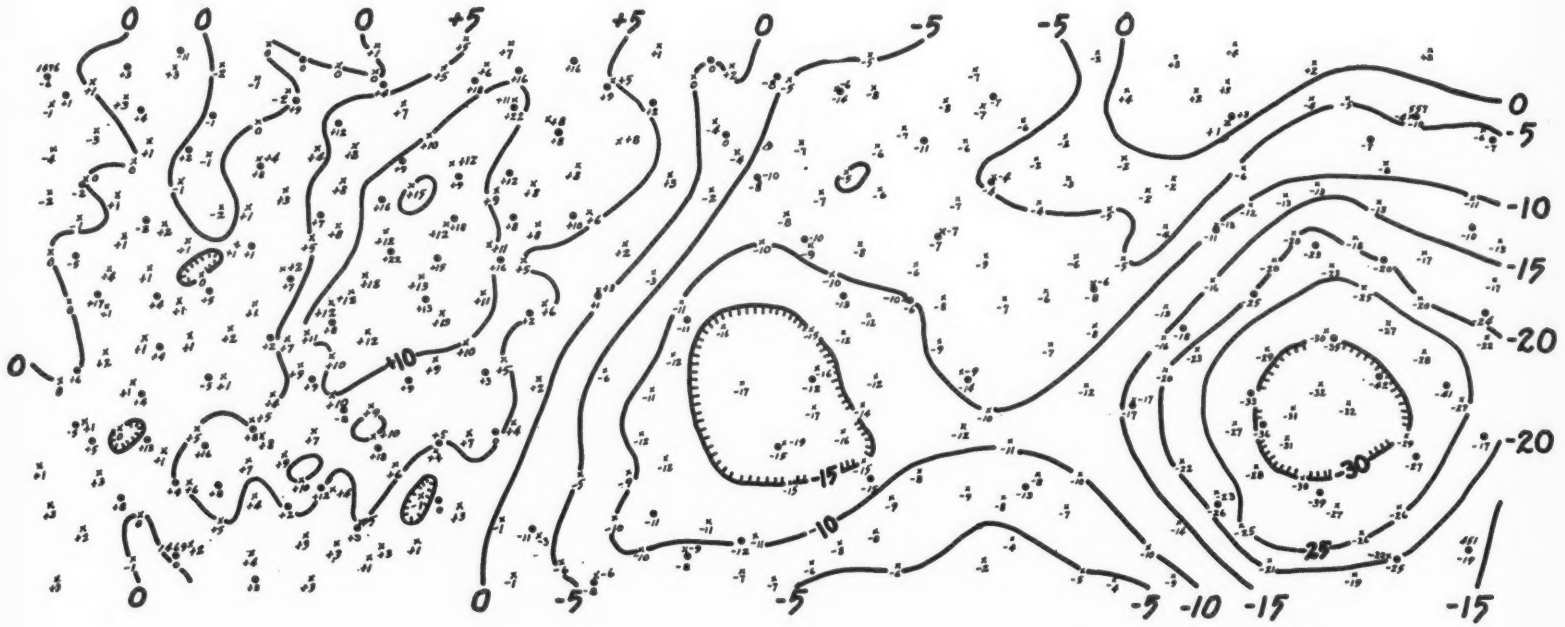


FIG. 3. Residual gravity over a portion of Texas Gulf Coast—gravimeter data. Gravity values are in 0.1 milligal units. Contour interval is 0.5 milligal.

×—gravimeter station

●—pendulum station, or pendulum and gravimeter station

general agreement between Figs. 2 and 3 is striking and is evidence that the reliability method aids in discriminating between spurious and reliable anomalies. It is interesting to note that Fig. 3 still shows a small amount of "noise," which could be eliminated, if desired, by using the reliability method on the new data.

(2) *A Gravimeter Survey in the Cleveland Hills Area, Yorkshire County, England*

The observed gravimeter data and contours are shown on the left half of Fig. 4. It is estimated that the probable error of the values is about 0.3 mg.; most of this is thought to be due to insufficient terrain corrections in an area of rough topography.

This survey is shown to illustrate two interesting special points in the application of the method. First, the innermost contour marked *A* is shown by the method to be unreliable. That is, we would not be at all surprised if the addition of more stations or the use of more precise data would shift the contour to another location or remove it completely. Second, the next contour surrounding contour *A* is shown by the method to be reliable in general but the indentation marked *B* is not reliable. Consequently more data or more precise data might remove or change the shape of the indentation. Both these predictions are borne out by the contours shown on the right half of Fig. 4, which are from the same data with much more accurate terrain corrections.

(3) *A Soil Gas Survey Over the Salskii Steppes Area, South of Stalingrad, Union of Socialistic Soviet Republics*

The soil gas data[6] are shown on Fig. 5. This profile has been selected because it is the only published case known to the writer of a survey which covers equally well both normal and anomalous areas. The portion of the profile from samples 70 to 80 presumably represents either a residual error in the analyzing apparatus or the normal value over this area. From the appearance of the profile the latter hypothesis seems more reasonable and will be adopted. Such a normal value may be considered analogous to a "regional" and should be subtracted from the values over the anomalous areas. The "regional" adopted is shown on the profile as a dotted line. This line represents a value of 5 in some arbitrary unit.

[6] The data are from Fig. 52 of V. A. Sokolov, "Gas Surveying," edited by I. M. Gubkin, English translation from the Russian by A. A. Boehtlingk, 1939.

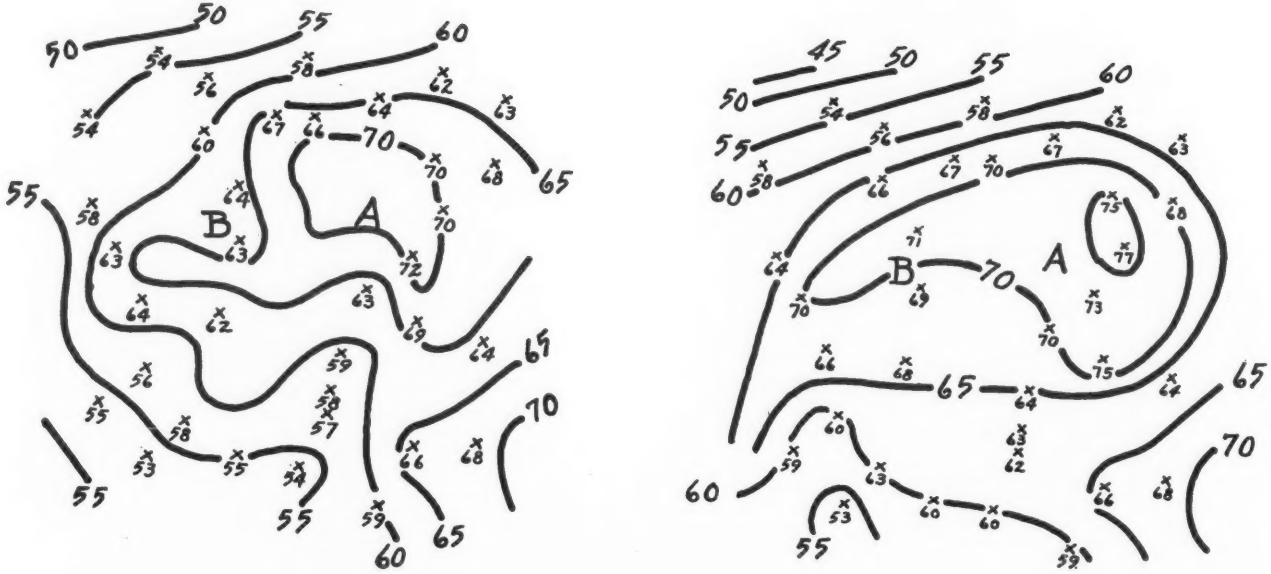


FIG. 4. Gravimeter survey over portion of Cleveland Hills area, Yorkshire County, England. Data on left side are before, on right side after, more accurate terrain corrections were made. Gravity values are in 0.1 milligal units. Contour interval is 0.5 milligal.
×—gravimeter station

Sokolov makes no estimate of the standard deviation for this case; we shall adopt a value of 5 for purposes of illustration because this value seems reasonable in view of the errors of 25 to 30 per cent which Sokolov mentions.[7] With this value of the standard deviation the highs (measured with respect to the regional) of the portion of the profile above the gravity maximum at Chernyi Yar are not reliable. On the other hand the jagged high on the northwest side of the gravity minimum at Solenoyo Zaimishche is reliable. This reliability is based

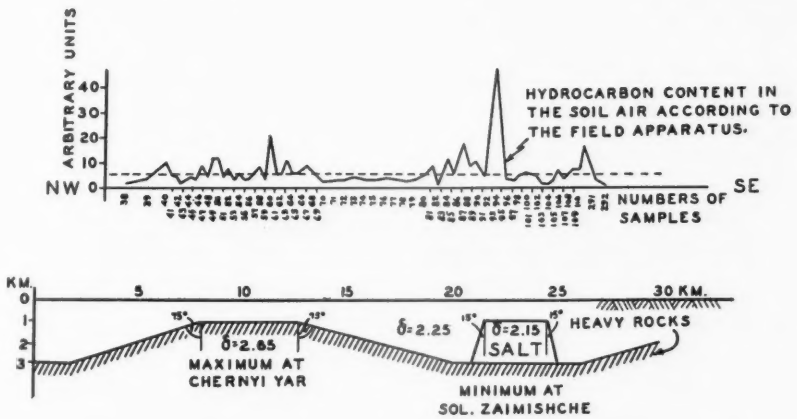


FIG. 5. Gas profile through the gravimetrical structure at the Chernyi Yar and Solenoyo Zaimishche (1934 by Ya. Eventov). (After Fig. 52 of "Gas Surveying," by V. A. Sokolov.)

on the large number of points showing positive values over this section. The remainder of the Solenoyo Zaimishche profile is mostly below the "regional" datum and from the view-point of our analysis is not significant.

This survey is a good example of the importance of the "regional" and the standard deviation (or probable error) of the data in judging the reliability of anomalies. It must be remembered that both must be known before it is possible to apply the method of judging reliability which we have described in this paper. The writer was unable to find a single published example of soil or soil gas analysis data for which either was given; this point is mentioned to emphasize the fact that the estimates used for the Sokolov survey are the writer's own and that Sokolov himself might not agree to them.

[7] See page 231 of the translation mentioned in the previous footnote.

CONCLUSION

An important point in regard to ranking or discarding anomalies on probability considerations is the obvious one that other relevant information is considered and from the practical view-point, should be considered, in judging anomalies. Thus the very fact that in our discussion above of the gravity maps we instinctively picked certain types of anomalies, such as closures or indentations, itself indicates that we are using other information than that offered by probability theory. There is no reason for not doing so; however it is certainly worth while to keep separate mentally what is justified by probability theory and what comes from other sources. From that view-point this paper treats the simplest case, and it is easy to think of much more complicated problems.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation for the assistance given by Mr. W. L. Dowler in the preparation of the figures. He is also indebted to Drs. P. D. Foote and E. A. Eckhardt for permission to publish this paper.

APPENDIX

A Proof that the Averaging Method is Always Conservative

Let the probability of occurrence of an error equal to or greater than $m\sigma$ be denoted by $f(m)$. Then we wish to prove that

$$f(m_1) \cdot f(m_2) \cdot \cdots f(m_n) < \left[f\left(\frac{m_1 + m_2 + \cdots + m_n}{n} \right) \right]^n,$$

where none of the m's is negative and not all of them are equal. This is equivalent to the statement that the probability for the occurrence of n independent errors of the same sign and equal to or greater in absolute value than $m_1\sigma, \cdots, m_n\sigma$ respectively is less than the probability of the occurrence of n independent errors of the same sign each equal to or greater in absolute value than the average of the previous n errors. Therefore, with the averaging process we shall find a greater probability that an anomaly is due to errors than we should by the accurate method and in critical cases may discard an anomaly when we should not. This is what we mean when we say that the method is "conservative."

We shall first prove the theorem for $n = 2$. We have defined

$$f(m) = \frac{1}{\sigma\sqrt{2\pi}} \int_{m\sigma}^{\infty} e^{-x^2/2\sigma^2} dx = \frac{1}{\sqrt{2\pi}} \int_{m}^{\infty} e^{-y^2/2} dy.$$

Let us consider the product

$$F = f(h) \cdot f(a - h),$$

in which h is non-negative and a is a positive constant and attempt to find the value of $h \leqq a$ for the maximum value of F. The condition for an extreme value turns out to be

$$e^{h^2/2} f(h) = e^{(a-h)^2/2} f(a - h).$$

An obvious solution is $h = a/2$. We must now show that this value of h is the only value which satisfies this equation. Set

$$G = e^{h^2/2} f(h)$$

and compute

$$\frac{dG}{dh} = he^{h^2/2} f(h) - \frac{1}{\sqrt{2\pi}}.$$

We can show that dG/dh is negative for finite $h \geqq 0$. First, $he^{h^2/2}$ is obviously an increasing function of h while $f(h)$ is a decreasing function of h for $h \geqq 0$. Therefore, the maximum value for the first term in the interval $a \leqq h \leqq b$ is never greater than the quantity $b\, e^{b^2/2} f(a)$. By actual numerical evaluation for the intervals $0 \leqq h \leqq 0.5$, $0.5 \leqq h \leqq 0.75$, $0.75 \leqq h \leqq 1$, $1 \leqq h \leqq 1.2$, $1.2 \leqq h \leqq 1.3$, $1.3 \leqq h \leqq 1.4$, $1.4 \leqq h \leqq 1.5$, $1.5 \leqq h \leqq 1.6$, $1.6 \leqq h \leqq 1.7$, $1.7 \leqq h \leqq 1.75$, $1.75 \leqq h \leqq 1.8$, $1.8 \leqq h \leqq 1.85$, $1.85 \leqq h \leqq 1.9$, $1.9 \leqq h \leqq 1.95$, $1.95 \leqq h \leqq 2$; we find that this quantity is less than $1/\sqrt{2\pi}$. Next, for $h \geqq 2$, we make use of the asymptotic expansion of $f(h)$,[8]

$$f(h) \sim \frac{1}{\sqrt{2\pi}} \frac{e^{-h^2/2}}{h} \left[1 - \frac{1}{h^2} + \frac{1 \cdot 3}{h^4} - \frac{1 \cdot 3 \cdot 5}{h^6} + \cdots \right].$$

Thus

$$\frac{dG}{dh} \sim \frac{1}{\sqrt{2\pi}} \left[-\frac{1}{h^2} + \frac{1 \cdot 3}{h^4} - \cdots \right].$$

For $h \geqq 2$, since the absolute value of the error made in stopping with the first term of this asymptotic expansion is less than the absolute value of the next term,[8] we see that dG/dh is negative for finite $h \geqq 2$.

[8] See page 332 of T. J. I.'A. Bromwich, "An Introduction to the Theory of Infinite Series," 2nd Edition, London: Macmillan and Co., Limited, 1926.

Thus we have shown that dG/dh is negative for finite values of $h \geqq 0$ and approaches zero as h approaches positive infinity. G then is a decreasing function of h as h varies from 0 to ∞. The equation which expresses the condition for the extreme value of F can then have but one finite value of h which satisfies it; for the left hand side (for values of h increasing from 0 to a) starts at a greater value than the right hand side and decreases steadily while the right hand side increases steadily.

In F, set $k=a-h$. Then $F=f(h)\cdot f(k)$, which is less than the maximum value of F, $\left[f\left(\frac{h+k}{2}\right)\right]^2$ Therefore for h and k non-negative,

$$f(h)\cdot f(k) < \left[f\left(\frac{h+k}{2}\right)\right]^2,$$

unless h and k are equal, in which case the inequality becomes an equality. Thus the theorem is proved for $n=2$.

Making use of the result for $n=2$, we shall prove the general case by means of a type of argument which has been employed in the proof that the geometric mean of n positive numbers is not greater than their arithmetic mean.[9] Let us consider the two quantities

$$A=f(m_1)\cdot f(m_2)\cdot\cdots f(m_n) \quad \text{and} \quad B=\left[f\left(\frac{m_1+m_2+\cdots+mn}{n}\right)\right]^n,$$

where none of the m's are negative. If all the m's are equal, A obviously equals B. If they are not all equal, replace the least and greatest of them, say m_1 and m_n, by $(m_1+m_n)/2$. By the result just proved for $n=2$, this will increase the value of A. However, B will be left unchanged. If the new m's are not all equal, replace the least and greatest as before. By continuing the process we can make A approach B as closely as we wish. But since B has not changed at all during the process while A has increased each time, it follows that the original A was less than B. Therefore

$$f(m_1)\cdot f(m_2)\cdot\cdots f(m_n) < \left[f\left(\frac{m_1+m_2+\cdots+m_n}{n}\right)\right]^n,$$

unless all the m's are equal, in which case the inequality becomes an equality.

[9] See page 47 of G. Chrystal, "Algebra," Part II, 2nd edition, London: A. and C. Black, Ltd., 1931.

TRANSIENT TESTING OF SEISMIC RECORDING APPARATUS*

HAROLD WASHBURN† AND RAYMOND OLESEN†

ABSTRACT

A transient generator and shaking table suitable for testing response characteristics of seismometers and associated amplifier and recording equipment is described. From variable-area sound-on-film records representing idealized transients or actual field seismograph recordings, the generator and shaking table provide a high-fidelity conversion to mechanical motion of the test table. The special experimental truck used in obtaining test records is also described briefly.

Improvements in the art of seismic prospecting require the study of many problems which involve the transient behavior of both apparatus and earth-motion. Such a study is greatly facilitated by apparatus which is capable of handling transient as well as steady state phenomena. It is the purpose of this paper to describe three pieces of equipment which when combined make possible an experimental approach to a large number of transient problems. The devices to be discussed are a transient generator, an experimental recording truck, and a shaking table.

It should be emphasized at this point that the equipment has been used purely for research and experimental purposes and that it has not been used nor is it particularly adapted to routine field operations.

TRANSIENT GENERATOR

In principle the transient generator resembles sound-on-film recording of the variable area type. It is used to generate simultaneously four different voltages of any desired wave shape. The waves produced may be of simple shape, such as square waves, damped sine waves, etc.; or they may be made the exact duplicate of the complicated voltage waves produced by four seismometers or seismometer groups as a result of a field shot.

Fig. 1 is a view of the transient generator. Each of the four large drums holds a strip of 35 mm. film, 30 inches long. On each of these films is a variable-area record of the desired voltage wave.

The eyepiece contains a stroboscopic light so that the drum speed may be accurately set.

* Presented at the Annual Meeting, Chicago, April 9, 1940.

† United Geophysical Co., Pasadena, California.

Fig. 2 is another view of the transient generator with its cover removed to show the amplifier assembly. The housing on the right contains a phonograph motor for driving the drums.

Fig. 3 is a schematic diagram of the optical equipment of the transient generator. The objective lens is adjusted to throw an image of the lamp filament on the optical slit. The opaque portion of the film directly in front of the slit intercepts part of this light and thus controls the length of the slit through which light is passed. The col-

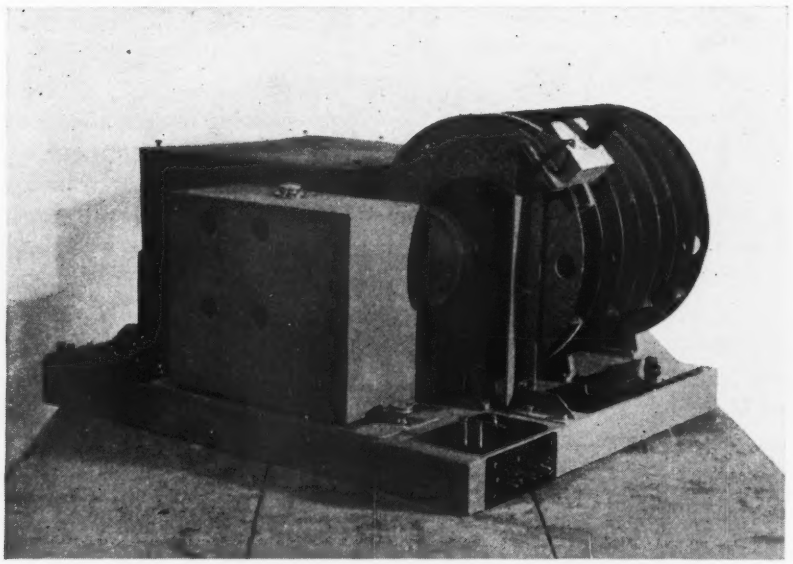


FIG. 1. The transient generator.

limator lens immediately behind the slit is so designed that it images the objective lens on the photocell. With this lens arrangement the light incident on the photocell is a disc of light which varies in intensity but does not change in size or position. A slit of light of variable length is thus transformed into a disc of light of variable intensity. This feature is important for accurate work since the surface of the photocell cathode is, in general, not of uniform sensitivity.

Fig. 4 is a wiring diagram of one of the amplifiers associated with the photocells in the transient generator. The high fidelity of this amplifier is made possible by a large amount of feedback. The output transformer is of special design and has an exceptionally high primary

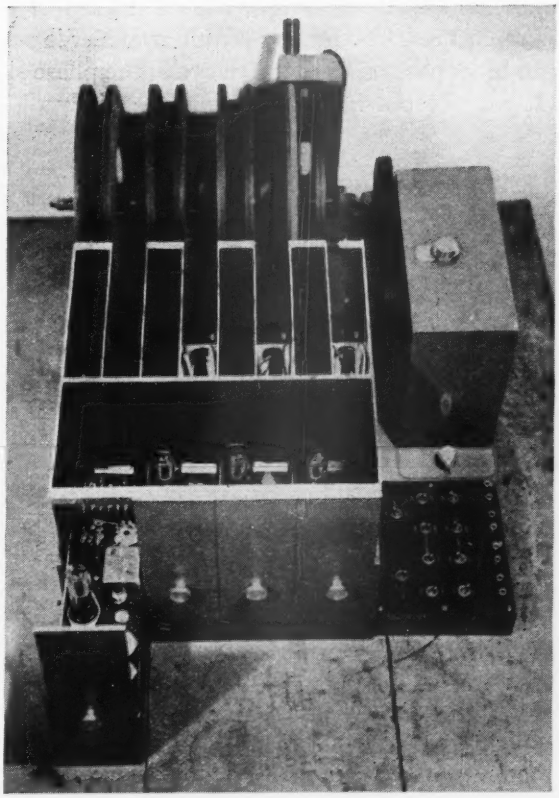


FIG. 2. Transient generator showing four components, their photo-cells and associated amplifiers.

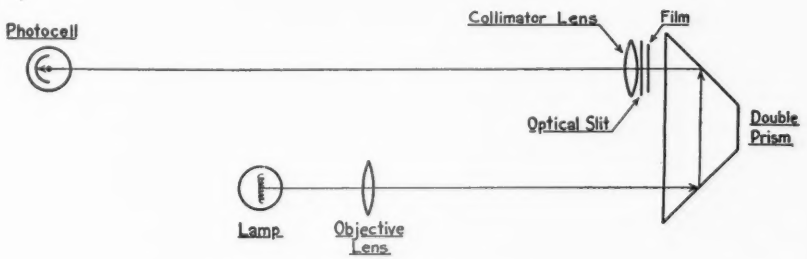


FIG. 3. Optical system of transient generator.

inductance (800 henrys) in order that the feedback will work effectively at low frequencies. The fidelity of this amplifier is perhaps best stated in terms of its phase shift—at five cycles the phase shift is only 10 degrees. It may be considered as being essentially distortionless

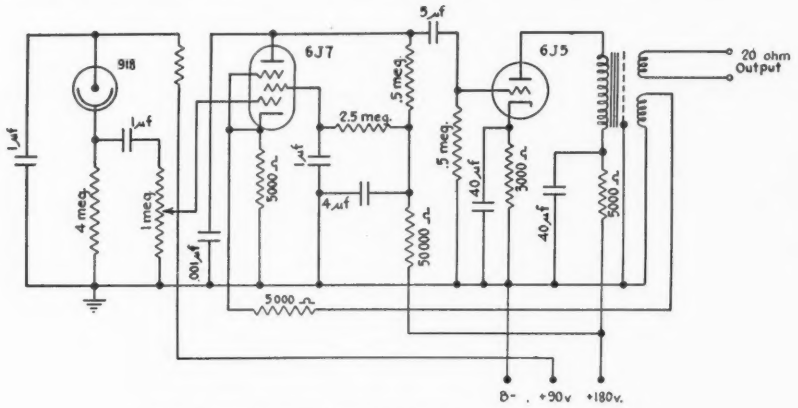


FIG. 4. Photo-amplifier circuit of transient generator.

between 7 and 2000 cycles. Its power output is one fifth of a watt into an impedance of 20 ohms.

The transient generator has been found especially useful in two general types of problems:

(1) The study of patterns of interfering reflections. (This application is described in another paper.)
(2) A study of the effect of seismometer, amplifier, and oscillograph response characteristics on the legibility and accuracy of reflections.

For this second problem the output voltages of high-fidelity seismometers are recorded with special apparatus mounted in an experimental recording truck. These records are transformed into variable area records merely by blacking the area on one side of each trace with India ink. Each trace is then photographed on 35 mm. film which is in turn used on the transient generator.

EXPERIMENTAL RECORDING TRUCK

Fig. 5 is a view of the instruments in the experimental truck. On the first two racks in the left foreground, only one of which is visible, can be mounted 21 channels of standard amplifiers together with their mixing and control panels. On the third rack are mounted six high-

fidelity amplifiers. These amplifiers have the same high fidelity as the wave generator amplifiers. To the right and ahead of these amplifier racks is the oscillograph camera. The galvanometers in the camera are

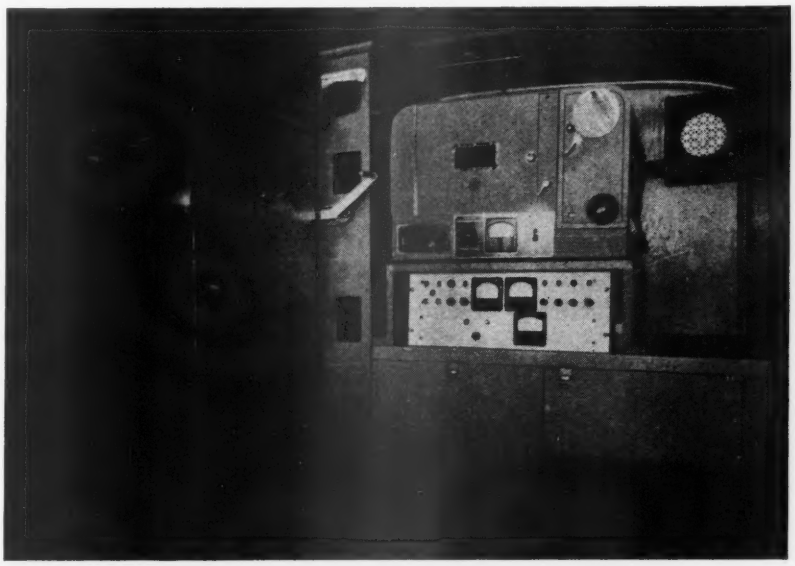


FIG. 5. Experimental truck equipment.

electro-magnetically damped and have a damping ratio of 20 to 1. Six of the galvanometers are 400-cycle elements used in conjunction with the high-fidelity amplifiers. All connections in the truck are formed with plugs and jacks so that rapid changes can be made. This truck can take standard 21-trace records or 6-trace high-fidelity records or a combination of both.

Fig. 6 is a wiring diagram of one of the high-fidelity amplifiers. It consists of three two-stage feedback circuits in series. The gain of the

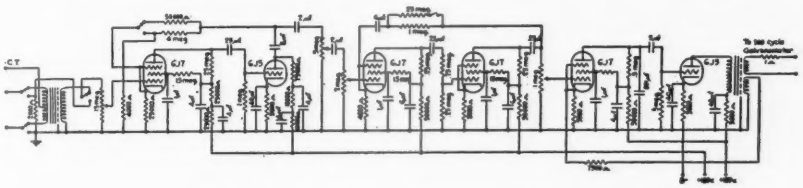


FIG. 6. High fidelity seismometer amplifier.

amplifier may be varied gradually over a range of 70 d.b. by means of the attenuators located between the second and third stages. The gain-control attenuators are so designed that their operation will not cause low frequency shift in the traces. They are placed here rather than ahead of the first stage to avoid noise generated by the gain-control. These amplifiers have a maximum gain of 80 d.b. and will take a kick of one volt without distortion when set at their low-gain position. They are essentially distortionless between 7 and 2000 cycles.

SHAKING TABLE

The third piece of equipment, one that has been found very valuable in the design of seismometers, is a shaking table. Fig. 7 is a drawing showing the construction of the shaking table, which is of the reaction type electromagnetically driven.

The table consists of a large mass approximately cubical in shape. This mass is machined flat on top to accommodate one or more seismometers. It is suspended by four groups of rubber bands, and the natural period of the system, both as a pendulum and as a loaded spring, is approximately one second. The rubber bands have been found very satisfactory. Their light weight, and the friction between adjacent strands, prevent oscillation of the suspension from affecting measurably the motion of the table.

The table is driven by a mechanism very similar to a dynamic loudspeaker. The electromagnet for imparting vertical motion is suspended from the table by a second set of rubber bands. The natural frequency of this system is about 1.5 cycles per second. The voice or driving coil is fastened rigidly to the table. The air gaps are made very large to prevent rubbing of the driver-coil on the electromagnet. Horizontal motion is imparted to the table by a second electromagnet and driver coil.

Extensive tests have been made to determine the accuracy of the shaking table motion. First, crystal pickups were used whose resonant frequency was well above the frequencies being measured. These tests show that from 10 to 2000 cycles the response of the table is flat within two d.b.

A second set of tests which permitted the measurement of the phase angle between the table motion and the input current was then carried out. These tests first determined the relation between the voltage output of a dynamic seismometer and its motion. This seismometer was then used as a standard for calibrating the shaking table. The procedure more in detail was as follows:

Two seismometers were bolted rigidly together and hung on rubber bands to simulate free suspension. A voltage was applied to one seismometer which acted as a driver to shake the pair. The output voltage produced in the second or detector seismometer and the phase angle

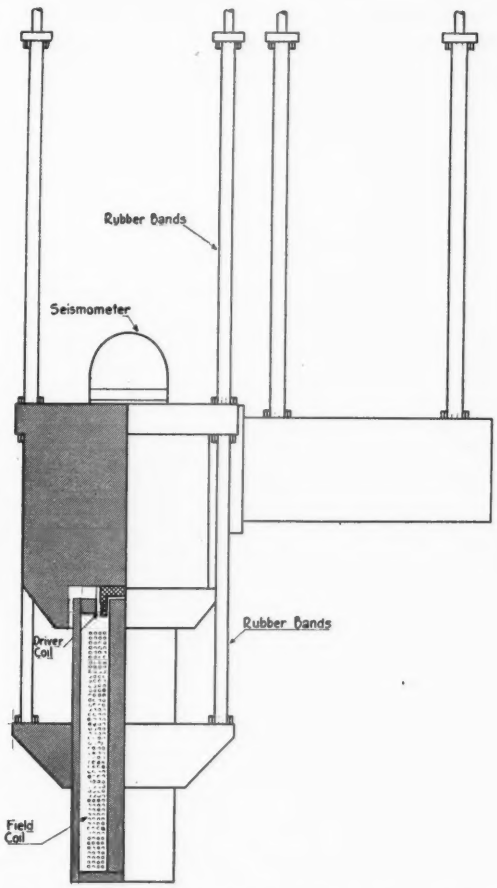


FIG. 7. Diagrammatic sketch of the shaking table.

between the driver and detector voltages were then measured for a range of frequencies from 10 to 400 cycles.

Next, the frequency, damping, and coil impedance of these seismometers were determined by weight lifting and bridge measurements. From these data, theoretical values of driver and detector voltages were computed for the condition of free suspension.

The theoretically computed values thus obtained agree very closely with the experimental results as shown in Fig. 8. Therefore, the response characteristics of the seismometers were accurately determined by the weight-lifting and bridge measurement data. These data were used to determine the relation between the voltage output of a single seismometer and its motion.

One of these seismometers was then placed on the shaking table. Measurements over a range of frequencies from 10 to 400 cycles were

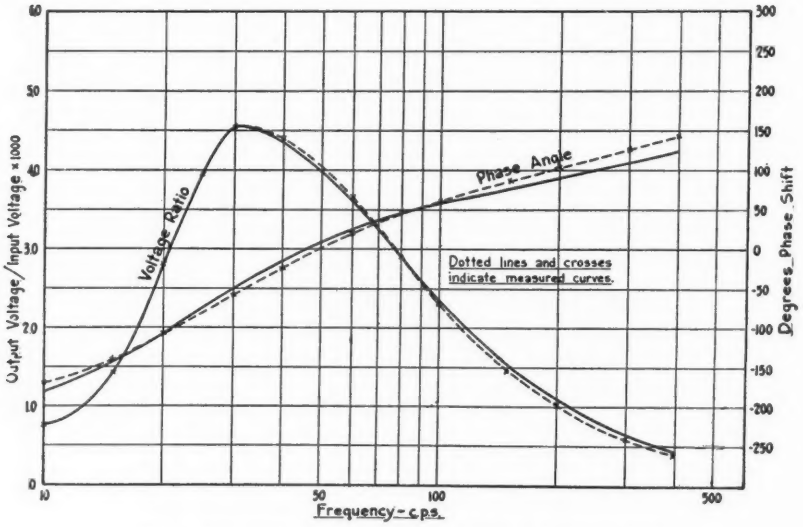


FIG. 8. Transmission characteristics of two seismometers bolted together.

made of the current in the driving coil of the shaking table, the voltage output of the seismometer, and the angle between these two quantities. From these data and the above determined characteristics of a single seismometer the relation between the shaking table motion and the current in its driver-coil was determined.

Fig. 9 shows a plot of the amplitude and phase of this relation. The acceleration of the shaking table is constant within ± 2 d.b. for a constant current in the driver-coil, and the acceleration and current in the driver-coil are out of phase by a possible 5 degrees only. Thus, for the frequency range normally recorded in a seismograph record, the motion of the table can be considered as faithfully following the transient current in its driver-coil.

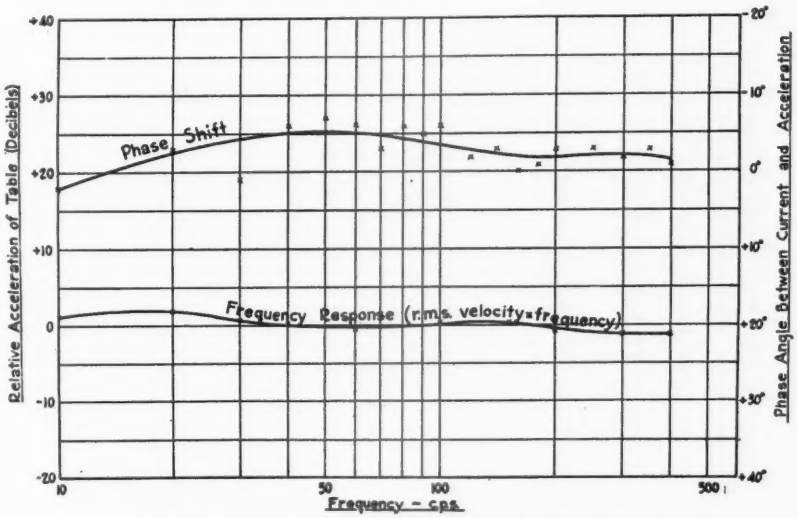


FIG. 9. Response curves of dynamic shaking table with constant current input.

The magnitude of the acceleration imparted to the shaking table by unit current in the driver-coil was determined in the following manner: In the experiment with two seismometers bolted together and suspended by rubber bands it was found that the motion of the driver-coil was large enough to be measured directly. From this value and the relative masses of the driver bobbin and the seismometer cases the amplitude of motion of the cases was readily computed. Since in the above experiment the voltage output of the detector seismometer was also measured, the relation between this voltage and the seismometer motion was obtained. The shaking table was then calibrated using this seismometer as a standard. The table acceleration was found to be 140 inches/sec^2 for one ampere through its driver-coil.

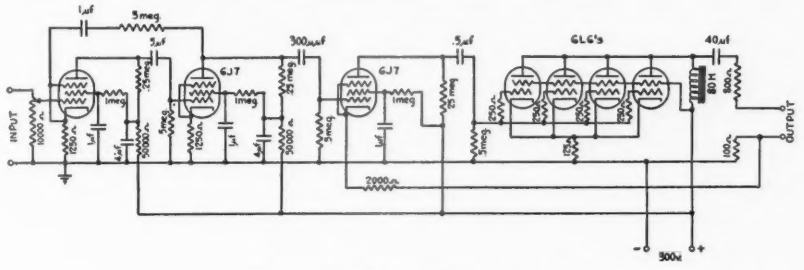


FIG. 10. Shaking table amplifier.

An experiment was next performed to test the fidelity of the shaking table in producing transient motion. A high-fidelity power amplifier, shown in Fig. 10, was constructed so that it forced a current through the driver-coil proportional to the derivative of the voltage input to this amplifier. This derivative feature is obtained by using a small coupling condenser (300 micro-microfarads) between the second

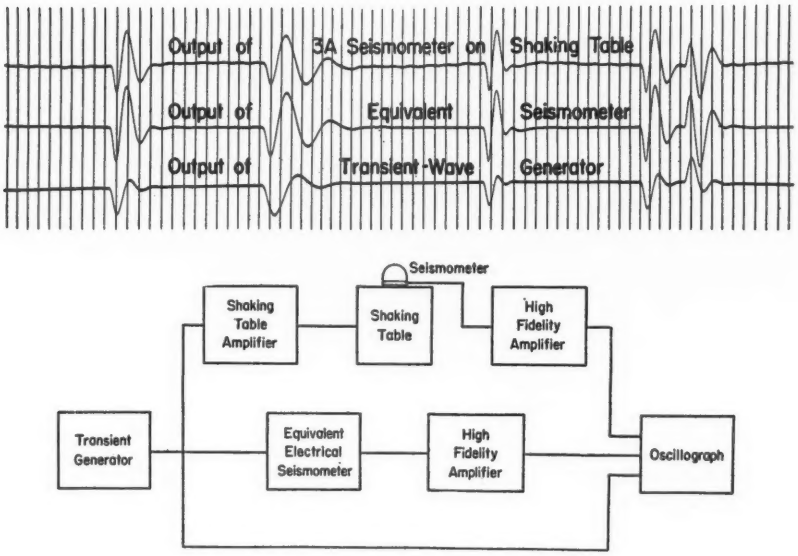


FIG. 11. Schematic diagram of equipment used to test the fidelity of transient response of the shaking table and resultant record showing faithful reproduction of transient motion.

and third stages of the amplifier. In other words, this amplifier made the volocity of the shaking table proportional to the voltage applied to the power amplifier. An equivalent electrical circuit of the seismometer to be used in the test was constructed. The output of the transient generator was then connected so as to furnish identical voltages to the equivalent electrical seismometer and to the shaking table power amplifier. The output of both the equivalent electrical seismometer and the actual seismometer placed on the shaking table were then simultaneously recorded. Fig. 11 shows the resulting record. The outputs of the equivalent and actual seismometers agree very closely.

Without question, then, the shaking table faithfully reproduces transient motion.

This device has been found of great value in testing new seismometer designs.

Thus it is seen that the combination of the experimental recording truck, the transient generator, and the shaking table makes possible the direct study of the transient behavior of the seismometer, amplifier, and oscillograph either separately or combined. In addition, this equipment may be used to advantage in ground motion studies and record-interpretation problems.

THE FORM AND NATURE OF SEISMIC WAVES AND THE STRUCTURE OF SEISMOGRAMS*

NORMAN RICKER†

ABSTRACT

A theory is presented to account for the structure of seismograms. It is demonstrated mathematically that a sharp seismic disturbance gives rise to a traveling *wavelet*, of shape determined by the nature of the earth's absorption spectrum for elastic waves, and that a seismogram is composed of a succession of these wavelets, generally overlapping but sometimes in the clear. It is further brought out that it is the center of the wavelet which travels with a velocity characteristic of the medium, and that the wavelet broadens as it moves along in accord with a definite law. Experimental support of the theory also is presented.

I

INTRODUCTION

Perhaps the greatest difficulty in the use of seismic waves in prospecting lies in the very complicated nature of a seismogram. Even under the most favorable circumstances realized in practice, a seismogram due to seismic waves sent out by a simple shock at a distant point on the earth's surface, is very complicated. This complicated nature of a seismogram is not in accord with the ordinary elastic solid theory.

To review very briefly the theory of the propagation of elastic waves in solid bodies, the differential equation satisfied by the elastic displacement, χ, is

$$(\lambda + 2\mu) \text{ grad div } \chi - \mu \text{ curl curl } \chi = D \frac{\partial^2 \chi}{\partial t^2} \tag{1}$$

where λ and μ are the elastic constants of Lamé, D is the density of the medium and t is the time.

χ, being a vector point function, may be written as the sum of two vectors

$$\chi = \chi_1 + \chi_2 \tag{2}$$

where χ_1 is irrotational, and χ_2 is solenoidal. That is to say

$$\text{curl } \chi_1 = 0 \qquad \text{and} \qquad \text{div } \chi_2 = 0. \tag{3}$$

* Presented at the Annual Meeting, Chicago, April 11, 1940.

† The Carter Oil Co., Tulsa, Oklahoma.

The differential equation thus splits up into two differential equations

$$\nabla^2\chi_1 = \frac{D}{\lambda + 2\mu} \cdot \frac{\partial^2\chi_1}{\partial t^2} \tag{4}$$

and

$$\nabla^2\chi_2 = \frac{D}{\mu} \cdot \frac{\partial^2\chi_2}{\partial t^2} \tag{5}$$

where ∇^2 is Laplace's operator

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \tag{6}$$

The vector displacement thus has two components, χ_1 and χ_2 such that χ_1 is irrotational and is propagated as a longitudinal wave with velocity

$$v_1 = \left(\frac{\lambda + 2\mu}{D}\right)^{1/2} \tag{7}$$

and χ_2 is solenoidal and is propagated as a transverse wave with

$$v_2 = \left(\frac{\mu}{D}\right)^{1/2}. \tag{8}$$

Although the discussion which is to follow will apply both to longitudinal and to transverse waves, we shall concern ourselves primarily with the longitudinal wave since it is this wave which is employed in both refraction and reflection seismic prospecting.

We can also limit our discussion to plane waves advancing along the x axis without loss in generality in what is to follow. In this case our wave equation (4) becomes

$$\frac{\partial^2\chi_1}{\partial x^2} = \frac{1}{v_1^2} \cdot \frac{\partial^2\chi_1}{\partial t^2} \tag{9}$$

which has a general solution

$$\chi_1 = f_1(x - v_1 t) + f_2(x + v_1 t) \tag{10}$$

where f_1 and f_2 are perfectly arbitrary functions. The part f_1 represents a wave traveling in the direction of the positive x axis, while the part f_2 represents a wave traveling in the direction of the negative x axis.

In the case of each part, however, the wave form remains unchanged. Thus if the wave is due to an explosion, the wave (shown in Fig. 1) should be propagated without change in form and should be received at a distance as the same wave form. In media obeying strictly the

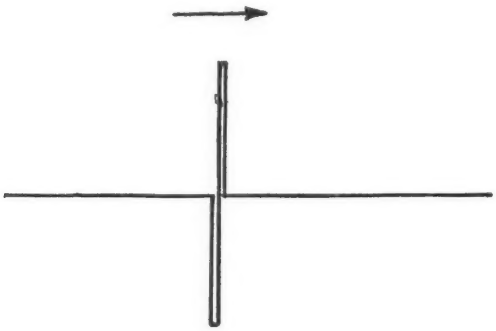


FIG. 1. Idealized wave form of shot impulse.

elastic equations, our seismogram, then, should consist of a succession of these knife-sharp disturbances, due to waves which have traveled different paths by refractions and reflections. Such an anticipated seismogram is shown in Fig. 2. In the propagation of compressional waves through water this state of affairs is fairly well realized, for in the echo method of deep sea sounding, the received waves are quite sharp, and

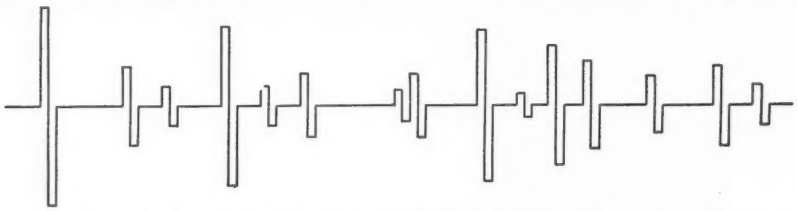


FIG. 2. Reflected and refracted events from idealized pulse propagated in an ideal medium, free from absorption.

this fortunate circumstance is responsible for the high degree of precision and dependability of this method of charting the depths of the oceans.

If such a sharp and clear-cut series of impulses constituted a seismogram from waves propagated through the earth, many of our difficulties in seismic prospecting would disappear. However, no such simple seismogram is received in the propagation of seismic waves through

the earth. Instead, we obtain a seismogram such as is shown in Fig. 3.

As the theory of elastic solids is ordinarily developed it is assumed that Hooke's Law is obeyed, a condition which is not justified except in the case of very hard solids such as hardened steel. In most solid bodies there is a plastic flow and an elastic hysteresis. These limitations of elastic solid theory are well known. References to these limita-

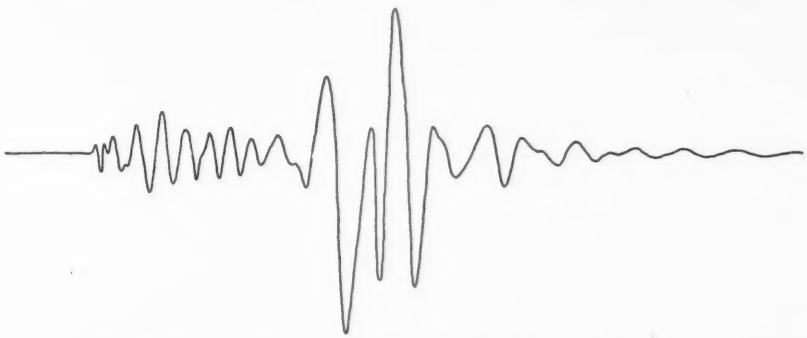


FIG. 3. Type of seismogram actually obtained from seismic waves propagated through the earth.

tions may be found, for instance, in Love's "Mathematical Theory of Elasticity."[1] To quote Love: "It is known that many materials used in engineering structures, e.g. cast iron, building stone, cement, do not obey Hooke's Law for any strains that are large enough to be observed. It is known also that those materials which do obey the law for small measurable strains do not obey it for larger ones." And again: "For hard metals it seems that there is no hysteresis with moderate load, but for rocks, such as granite and marble, there is hysteresis at quite moderate loads." Such a state of affairs existing for the firmer rocks such as marble and granite, and with most of the earth's near surface beds consisting of plastic clays and shales it should be clear that the strictly developed solutions of the wave equation for elastic solid bodies as given above should not give a true picture of the passage of elastic waves through the materials making up the earth's subsurface.

[1] A. E. H. Love, "A Treatise on the Mathematical Theory of Elasticity," 4th Edition. Chap. IV, pp. 112–124, Cambridge University Press, 1927. See also Adams and Coker "An Investigation into the Elastic Constants of Rocks," Carnegie Institute, 1906.

II

It has been the author's personal feeling for some time that this great difference in the nature of seismograms from waves due to explosions and propagated in the earth, over those propagated in water, is due to the absorption of the high frequency components of the wave as initially formed, as the wave advances through the earth.

It has been the author's experience, and very likely that of others as well, that high frequency vibrations are rather poorly transmitted by the earth while low frequency vibrations are transmitted quite well. Another manner of expressing it is that the earth has an absorption spectrum which tends to absorb high frequency waves to a much greater extent than low frequency waves.

Relative to the nature of this absorption spectrum, we know very little beyond what has just been stated. In the absence of more specific knowledge, but knowing that there is an increase in absorption with increasing frequency, we can investigate the effect of such an absorption band for various degrees of sharpness of its cut-off.

In the well known treatment of elastic solids the elastic constants are ordinarily treated as simple real constants because of the assumption that the stress is proportional to the strain. As has already been mentioned, this condition is only approximated in such materials as spring steel. Certainly in the case of earth materials the stress is not proportional to the strain. There is, for one thing, a plastic flow and an elastic hysteresis. The strain depends not only upon the stress applied but upon the length of time the stress acts. The matter is similar to the case of electromagnetic waves propagated through conducting bodies so that there exists a conduction current as well as a displacement current. The analogy is not complete, however, as the problem is not entirely a matter of simple viscosity as has been pointed out by Lord Kelvin.[2]

Because of the poor state of our knowledge of the manner in which energy is absorbed by the earth as the waves pass through it, the author feels that the best approach is through an assumed absorption spectrum of the earth.

It is well known from the theory of the propagation of light through electrically conducting media that a complex value of the refractive index and therefore of the velocity of light in the medium, results in absorption.

[2] Sir W. Thomson: Math. and Phys. Papers, Vol. 3, Cambridge, 1890, p. 27. See also reference in Love's "Math Theory of Elasticity," 4th Ed., p. 118.

In the case of elastic waves the same absorption results if the velocity of the waves is taken as a complex quantity. The velocity of the wave involves the density and elastic moduli of the medium, and since the density must be real the elastic moduli must be complex.

$$\begin{aligned} \lambda &= \lambda_1 + i\lambda_2, \\ \mu &= \mu_1 + i\mu_2. \end{aligned} \tag{11}$$

We have to be careful, however, as these elastic moduli will be different for different frequencies of vibration. So in integrating the wave equation we must assign the frequency before we can assign the values of the elastic moduli. In other words, we must obtain a solution of the wave equation for a definite frequency. We then can build up our desired solution from single frequency components. Limiting our further treatment to plane waves advancing along the positive x axis, these solutions will be of the form

$$\chi_1 = Ae^{-\alpha x}e^{i(2\pi\nu/v)(x-vt)} \tag{12}$$

where ν is the frequency of vibration of the wave, and α is the absorption coefficient.

This value of χ_1 satisfies the wave equation. In this solution we take α and v to be real quantities representing the absorption coefficient and the velocity of the wave respectively. By substituting this solution into the wave equation the complex value of $(\lambda+2\mu)$ may be obtained in terms of α, v, ν and D. Since the principal effect of plastic flow and other energy absorption phenomena will be to reduce the amplitude of vibration, we shall take the velocity, v, as independent of frequency. The absorption coefficient, α, however, will be a function of the frequency, ν. We know that α increases with increasing frequency. Relative to what this functional relation is we know very little. We may, however, represent α as varying as some power, q of the frequency. Thus we write

$$\alpha = k\left(\frac{\nu}{\nu_0}\right)^q \tag{13}$$

where ν_0 is some frequency which we shall call the "cut off frequency." Periodic waves advancing along the positive x axis can then be represented by

$$\chi_1 = e^{-(\nu/\nu_0)^q kx} \sin \frac{2\pi\nu}{v}(x - vt). \tag{14}$$

It should be mentioned, in passing, that ν_0 and k are not independent. We can replace these two constants by a single constant $m = k/\nu_0{}^q$ if we like.

In Fig. 4 are drawn curves representing the absorption spectrum of the earth with q as a parameter of the family of curves. It may be seen that q determines the sharpness of the absorption band's edge. With

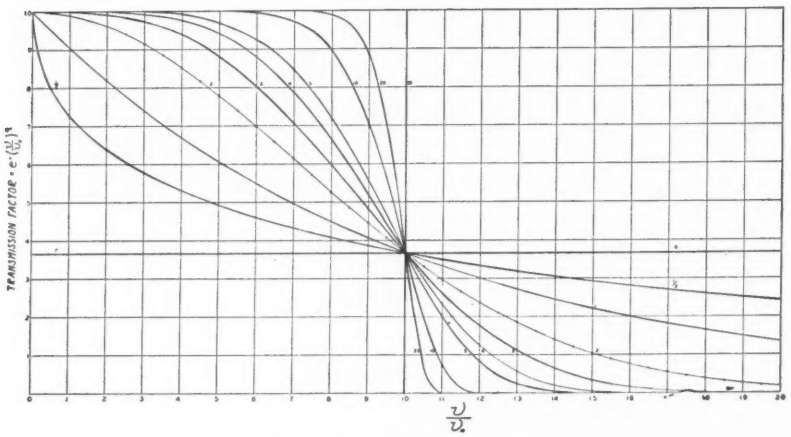


FIG. 4. Earth's absorption spectrum. The parameter of the family of curves is q.

increasing q the edge of the absorption band increases in sharpness, and, as q becomes infinite, the absorption is such that all frequencies below ν_0 are freely transmitted, while all frequencies above ν_0 are completely absorbed.

III

Let us now suppose that we have created a sharp seismic wave by means of an explosion, and then proceed to investigate the effect of the absorbing properties of the earth as this wave advances. We shall represent the initial wave form as shown in Fig. 5.

Representing the displacement in this wave as a function of x, say $f(x)$, we have

$$\begin{aligned} f(x) &= b \quad \text{when} \quad 0 < x < a \\ f(x) &= 0 \quad \text{when} \quad a < x < \infty \\ f(x) &= 0 \quad \text{when} \quad x = 0 \\ f(x) &= -b \quad \text{when} \quad -a < x < 0 \\ f(x) &= 0 \quad \text{when} \quad -\infty < x < -a. \end{aligned} \tag{15}$$

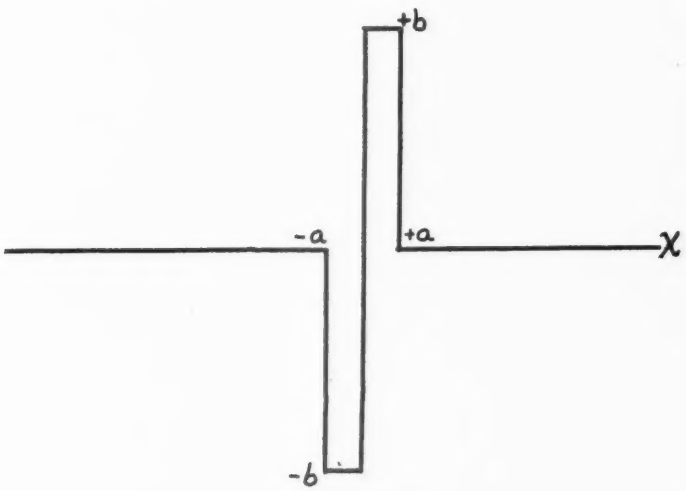


FIG. 5. Initial wave form.

$f(x)$ is an odd function of x and in this form may be represented by a Fourier Integral

$$f(x) = \frac{2}{\pi}\int_0^\infty f(\xi)d\xi \int_0^\infty \sin \eta\xi \cdot \sin \eta x \cdot d\eta. \tag{16}$$

$$f(x) = \frac{2}{\pi}\int_0^\infty \sin \eta x \cdot d\eta \int_0^a b \sin \eta\xi \cdot d\xi. \tag{17}$$

$$f(x) = \frac{2b}{\pi}\int_0^\infty \frac{\sin \eta x(1 - \cos \eta a)}{\eta} \cdot d\eta. \tag{18}$$

This integral represents the initially formed wave as described. η has dimensions $1/L$ or frequency/velocity, and since the velocity is a constant, the integration is in effect the summation of all single-frequency components in the wave from zero to infinite frequency. We must be able to replace η by its equivalent in terms of ν. It will be recalled that the Fourier integral is developed by extension of the interval from a Fourier series, whereby the interval $-\pi$ to $+\pi$ is changed to $-c$ to $+c$ and then c allowed to become infinite.

The series development is

$$f(x) = \sum_{n=1}^{\infty} a_n \sin \frac{n\pi x}{c}, \tag{19}$$

where

$$a_n = \frac{2}{c}\int_0^c f(\xi)\,\sin\frac{n\pi\xi}{c}\cdot d\xi, \tag{20}$$

whence

$$f(x) = \frac{2}{\pi}\int_0^c f(\xi)d\xi\sum_{n=1}^{\infty}\frac{\pi}{c}\sin\frac{n\pi\xi}{c}\sin\frac{n\pi x}{c}\cdot \tag{21}$$

Now as c is increased without limit, π/c becomes the infinitesimal $d\eta$ and $n\pi/c$ is of course η, and the summation then becomes an integral, so

$$f(x) = \frac{2}{\pi}\int_0^{\infty} f(\xi)d\xi\int_0^{\infty}\sin\eta\xi\cdot\sin\eta x\cdot d\eta. \tag{22}$$

Further, since c represented half a wave length of the fundamental frequency, $(c=\bar{\lambda}/2)$, and since n is the ordinal number of the harmonic of the fundamental frequency, it follows that the fundamental frequency is

$$\bar{\nu} = \frac{v}{\bar{\lambda}}; \qquad \bar{\nu} = \frac{v}{2c}\cdot \tag{23}$$

Thus

$$\frac{n}{c} = \frac{2\nu}{v} \tag{24}$$

So

$$\eta = \frac{n\pi}{c}\cdot \tag{25}$$

Or

$$\eta = \frac{2\pi\nu}{v}\cdot \tag{26}$$

And so our Fourier Integral development of the initial wave form becomes

$$f(x) = \frac{2b}{\pi}\int_0^{\infty}\frac{\sin\frac{2\pi\nu x}{v}\left(1-\cos\frac{2\pi\nu a}{v}\right)}{\nu}\cdot d\nu. \tag{27}$$

If we represent the wave to be traveling with a velocity v along the positive x axis the development becomes

$$f(x, t) = \frac{2b}{\pi}\int_0^\infty \frac{\sin\frac{2\pi\nu}{v}(x - vt)\cdot\left(1 - \cos\frac{2\pi\nu a}{v}\right)}{\nu}\,d\nu. \quad (28)$$

IV

Now if we inspect the integrand we see that the amplitude of the component of frequency ν is

$$\frac{1 - \cos\frac{2\pi\nu a}{v}}{\nu}\cdot d\nu. \quad (29)$$

If this component has passed a distance x through the earth its amplitude is then reduced to

$$\frac{1 - \cos\frac{2\pi\nu a}{v}}{\nu}\cdot d\nu\cdot e^{-(\nu/\nu_0)^q kx}. \quad (30)$$

And since the wave is the sum of its component single frequency elements we write

$$\bar{f}(x, t) = \frac{2b}{\pi}\int_0^\infty \frac{\left(1 - \cos\frac{2\pi\nu a}{v}\right)e^{-(\nu/\nu_0)^q kx}\cdot\sin\frac{2\pi\nu}{v}(x - vt)}{\nu}\,d\nu. \quad (31)$$

Upon evaluating this integral we should have the resultant wave form as modified by the earth's absorption.

The integral so written reveals the summation of single frequency components. It is more convenient, however, to replace ν by its equivalent in terms of η, in actually carrying out the integration, for simplicity of symbols. The integral is then

$$\bar{f}(x, t) = \frac{2b}{\pi}\int_0^\infty \frac{(1 - \cos\eta a)e^{-(\eta/\eta_0)^q kx}\cdot\sin\eta(x - vt)}{\eta}\cdot d\eta. \quad (32)$$

Now let a be very small, and we have

$$\bar{f}(x, t) = \frac{a^2 b}{\pi}\int_0^\infty \eta e^{-(\eta/\eta_0)^q kx}\cdot\sin\eta(x - vt)d\eta. \quad (33)$$

Let

$$u = \eta_0 \frac{x - vt}{(kx)^{1/q}} \quad \text{and} \quad \eta = \frac{\eta_0}{(kx)^{1/q}} \cdot \xi \tag{34}$$

where ξ is a new variable,
then

$$\bar{f}(x, t) = \frac{4\pi a^2 b \nu_0^2}{v^2 (kx)^{2/q}} \int_0^\infty \xi e^{-\xi^q} \sin \xi u \cdot d\xi, \tag{35}$$

or

$$\bar{f}(x, t) = \frac{K}{x^{2/q}} \cdot H_q(u) \tag{36}$$

where K is a constant and

$$H_q(u) = \int_0^\infty \xi e^{-\xi^q} \sin \xi u \cdot d\xi. \tag{37}$$

Calling

$$G_q(u) = \int_0^\infty e^{-\xi^q} \cos \xi u \cdot d\xi, \tag{38}$$

we see that

$$H_q(u) = -\frac{d}{du} G_q(u). \tag{39}$$

So we must evaluate the integral

$$G_q(u) = \int_0^\infty e^{-\xi^q} \cos \xi u \cdot d\xi. \tag{40}$$

We have

$$G_q(u) = \int_0^\infty e^{-\xi^q} \left(1 - \frac{u^2}{2!} \xi^2 + \frac{u^4}{4!} \xi^4 - \cdots\right) d\xi. \tag{41}$$

Now

$$\int_0^\infty \xi^p e^{-\xi^q} d\xi = \frac{1}{q} \Gamma\left(\frac{p+1}{q}\right), \tag{42}$$

so

$$G_q(u) = \frac{1}{q}\left[\Gamma\left(\frac{1}{q}\right) - \Gamma\left(\frac{3}{q}\right)\frac{u^2}{2!} + \Gamma\left(\frac{5}{q}\right)\frac{u^4}{4!} - \cdots\right]. \quad (43)$$

$$H_q(u) = \frac{1}{q}\left[\Gamma\left(\frac{3}{q}\right)u - \Gamma\left(\frac{5}{q}\right)\frac{u^3}{3!} + \Gamma\left(\frac{7}{q}\right)\frac{u^5}{5!} - \cdots\right]. \quad (44)$$

So

$$\bar{f}(x, t) = \frac{K}{x^{2/q}} H_q\left(2\pi \frac{\nu_0}{vk^{1/q}} \cdot \frac{x - vt}{x^{1/q}}\right). \quad (45)$$

This represents the elastic displacement as the disturbance passes and will describe the behavior of the trace of a mechanical seismograph. In the case of electrical seismographs with a geophone of the magnetophone type and an amplifier with uniform response for all frequencies, the trace will move as the derivative of this function with respect to time, so, if we write

$$\bar{f}(x, t) = \frac{K}{x^{2/q}} H_q\left(M \cdot \frac{x - vt}{x^{1/q}}\right) \quad (46)$$

$$\frac{\partial}{\partial t}\bar{f}(x, t) = -\frac{KMv}{x^{3/q}} \cdot \frac{d}{du} H_q(u). \quad (47)$$

So the derivative of $H_q(u)$ will enter in the description of the motion of the trace of an electrical seismograph.
So we must consider the three functions

$$G_q(u) = \frac{1}{q}\left[\Gamma\left(\frac{1}{q}\right) - \Gamma\left(\frac{3}{q}\right)\frac{u^2}{2!} + \Gamma\left(\frac{5}{q}\right)\frac{u^4}{4!} - \Gamma\left(\frac{7}{q}\right)\frac{u^6}{6!} + \cdots\right]. \quad (48)$$

$$H_q(u) = \frac{1}{q}\left[\Gamma\left(\frac{3}{q}\right)u - \Gamma\left(\frac{5}{q}\right)\frac{u^3}{3!} + \Gamma\left(\frac{7}{q}\right)\frac{u^5}{5!} - \Gamma\left(\frac{9}{q}\right)\frac{u^7}{7!} + \cdots\right]. \quad (49)$$

$$I_q(u) = \frac{1}{q}\left[\Gamma\left(\frac{3}{q}\right) - \Gamma\left(\frac{5}{q}\right)\frac{u^2}{2!} + \Gamma\left(\frac{7}{q}\right)\frac{u^4}{4!} - \Gamma\left(\frac{9}{q}\right)\frac{u^6}{6!} + \cdots\right]. \quad (50)$$

$$H_q(u) = -\frac{d}{du}G_q(u). \tag{51}$$

$$I_q(u) = \frac{d}{du}H_q(u) = -\frac{d^2}{du^2}G_q(u). \tag{52}$$

It will also be seen that these functions may be expressed by the integrals

$$G_q(u) = \int_0^\infty e^{-\xi^q}\cos u\xi \cdot d\xi. \tag{53}$$

$$H_q(u) = \int_0^\infty \xi e^{-\xi^q}\sin u\xi \cdot d\xi. \tag{54}$$

$$I_q(u) = \int_0^\infty \xi^2 e^{-\xi^q}\cos u\xi \cdot d\xi. \tag{55}$$

When $q=1$, 2 and ∞, these functions can be expressed in terms of elementary functions, and for these values of q we have the following table.

q	$G_q(u)$	$H_q(u)$	$I_q(u)$
1	$\frac{1}{1+u^2}$	$\frac{2u}{(1+u^2)^2}$	$2\cdot\frac{1-3u^2}{(1+u^2)^3}$
2	$\frac{\sqrt{\pi}}{2}e^{-(u/2)^2}$	$\frac{\sqrt{\pi}}{4}ue^{-(u/2)^2}$	$\frac{\sqrt{\pi}}{4}\left(1-2\left(\frac{u}{2}\right)^2\right)e^{-(u/2)^2}$
∞	$\frac{\sin u}{u}$	$\frac{\sin u - u\cos u}{u^2}$	$\frac{2u\cos u - (2-u^2)\sin u}{u^3}$

In Fig. 6 the functions $H_q(u)$ and $I_q(u)$ are shown graphically for several values of q. The function $I_4(u)$ was calculated from its series.

V

Aside from a general reduction in amplitude as the wave advances by virtue of the factor $1/x^{2/q}$ or $1/x^{3/q}$ from equations (46) and (47) the

functions $H_q(u)$ and $I_q(u)$ represent the form of the disturbance. So, while the single frequency components decay exponentially with the distance traveled, the wavelet amplitude does not.

We have been discussing plane waves. In the case of divergent spherical waves without absorption the amplitude should fall off inversely as the distance. When absorption is introduced we find then that the amplitude of the wavelets of such diverging waves should fall off as $1/x^{1+2/q}$ when $H_q(u)$ wavelets are being observed with a mechan-

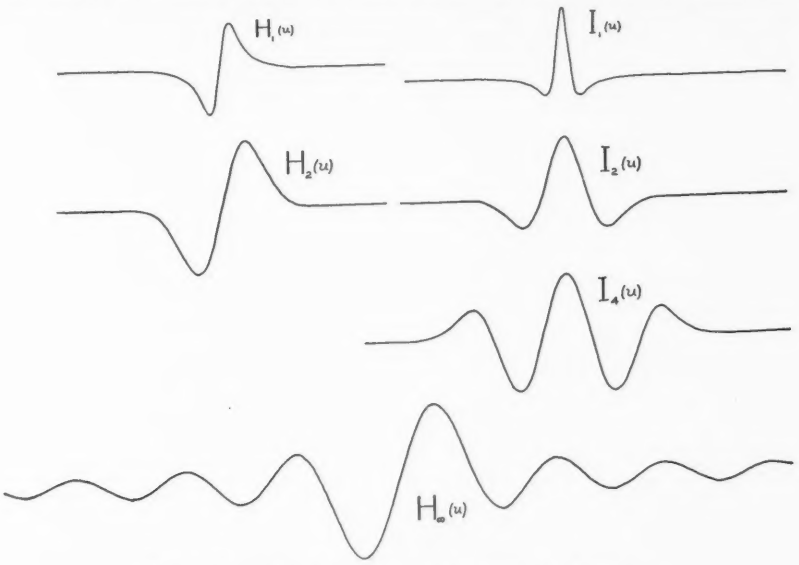


FIG. 6. Functions $H_q(u)$ and $I_q(u)$ for several values of q.

ical seismograph; and as $1/x^{1+3/q}$ when $I_q(u)$ wavelets are being observed with an electrical seismograph. For example, for $q=2$, the amplitude of divergent wavelets observed on an electrical seismograph should fall off inversely as the $5/2$ power of the distance.

Thus we see that the originally sharp wave form is transformed into a traveling "wavelet" of shape determined by the steepness of the cut-off of the earth's absorption spectrum.

Furthermore we see that it is the center of the wavelet which travels with the velocity characteristic of the medium.

Another prediction of this theory is that as the wavelet advances through the earth it continually broadens in a manner such that if we measure the breadth of the wavelet in seconds, say, the breadth is proportional to the qth root of the propagation time. In Figs. 7 and 8 are

shown the primary phases of a number of seismograms due to waves propagated through clays and shales. The primary wavelet is very well isolated and may be seen to be quite similar to the calculated wavelet $I_2(u)$. In Fig. 9 shape factors for $I_2(u)$ are shown. Upon meas-

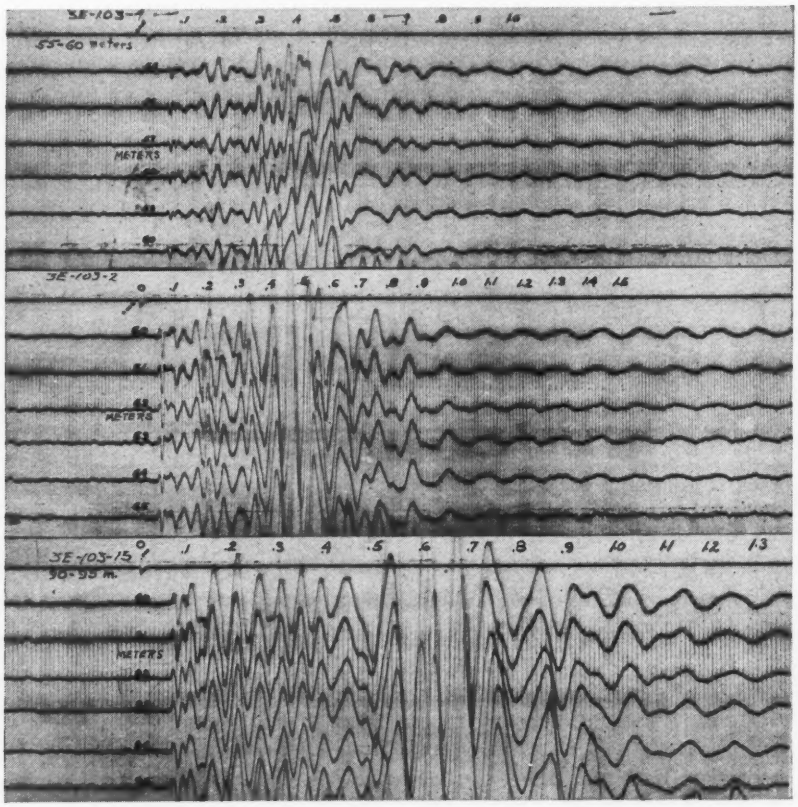


FIG. 7. Seismograms due to waves propagated through clays and shales.

uring up actually observed wavelets it will be found that the observed form factors agree very well with those given by the $I_2(u)$ wavelet form.

As a further check on the value of q we can plot log wavelet breadth, b, against log of propagation time. Actually observed points from these measurements are shown plotted in Fig. 10. The straight line drawn through these points has a slope $\frac{1}{2}$. Since, according to the theory just given, this slope should be $1/q$ it follows that $q=2$ from these measurements. Thus it should be evident that $q=2$ fits the ex-

perimental data best. From the treatment of the effect of ordinary viscosity in diminishing the amplitude of continuous periodic waves in air the absorption coefficient, α, should be proportional to the square

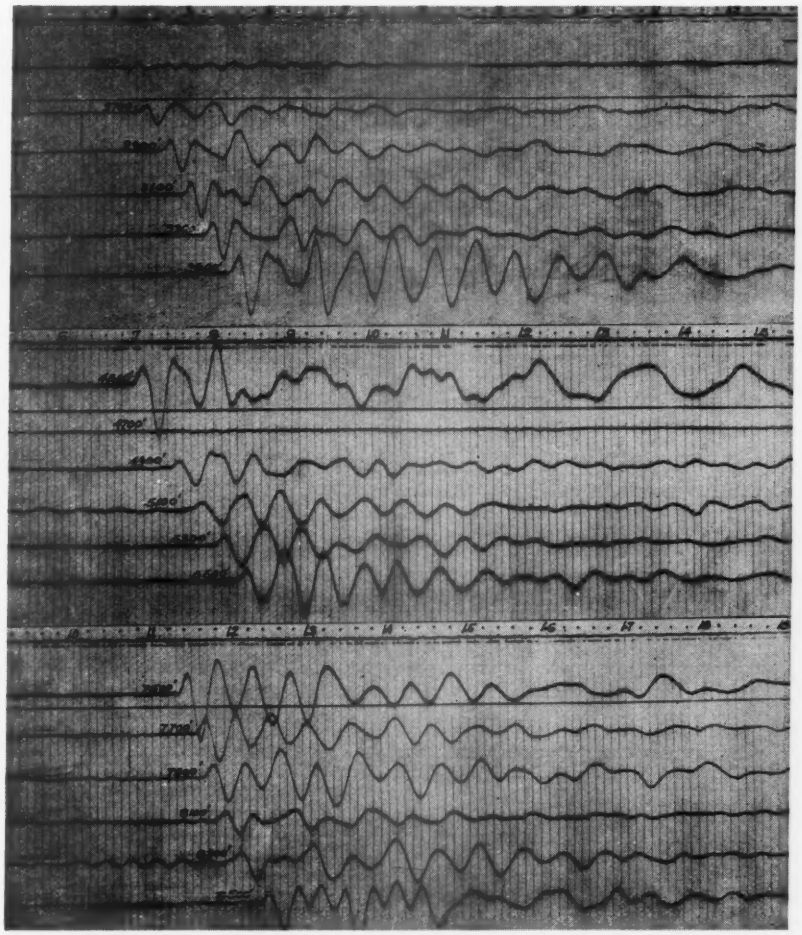


FIG. 8. Seismograms due to waves propagated through clays and shales.

of the frequency. This would indicate that our experimental finding of $q=2$ means that in these experimental observations, made in clays and shales in which one would expect great plasticity, ordinary viscosity was the predominating factor in the absorption phenomenon.

It is not advisable, however, to expect that other values of q will

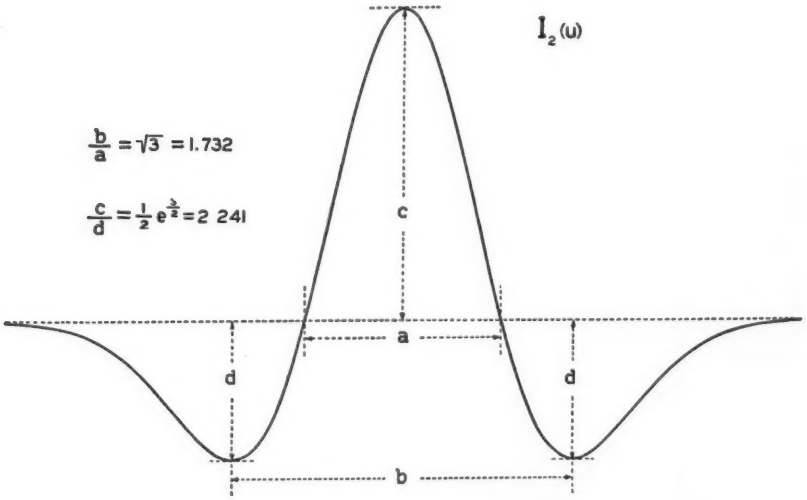


FIG. 9. Shape factors for $I_2^{(\omega)}$.

not be encountered, in view of our poor knowledge of the nature of internal friction in solids as mentioned in the reference to Lord Kelvin's observations. In view of the very important effect that this in-

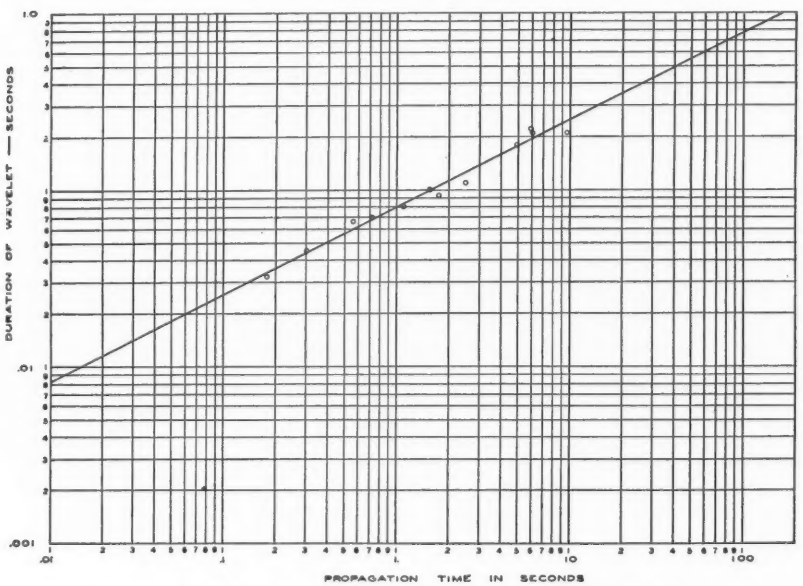


FIG. 10. Actually observed wavelet breadth vs. propagation time.

ternal friction has upon wave propagation in the earth we should know more about the earth's absorption spectrum for various geologic formations.

VI

The treatment in this paper has to do with "body waves"; waves which have traveled through the body of the medium in distinction from so-called surface waves of the Rayleigh type.

It should be clear, then, that aside from such surface waves, the seismogram should consist of a succession of wavelets, generally overlapping, but sometimes in the clear. We have seen the experimental

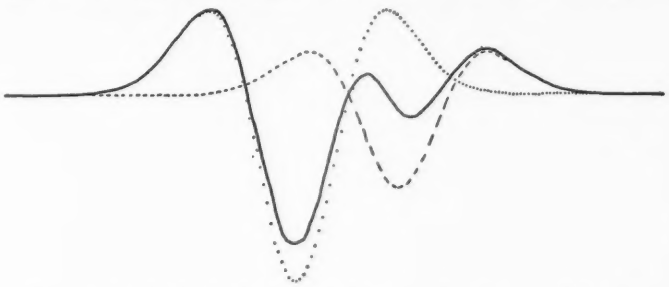


FIG. 11. Synthesized seismogram of two overlapping wavelets and resultant form.

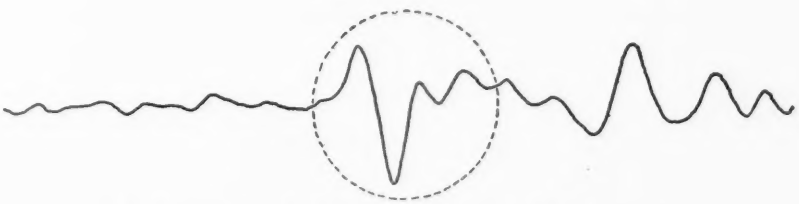


FIG. 12. Actual seismogram. (Compare with Fig. 11.)

evidence of clear, isolated wavelets in the primary phase of refraction seismograms, and how satisfactorily these wavelets conform with the mathematical theory here presented. We shall now see evidence of overlapping wavelets. In Fig. 11 is a sketch showing two wavelets drawn in accord with the theoretically anticipated form, displaced from one another and the second wavelet having half the amplitude of the first. These are shown by dotted lines. The heavy line represents the sum of these displacements. It is interesting to compare this "synthesized seismogram" with a tracing of a portion of an actual seismogram shown in Fig. 12. The similarity of the two traces is most interesting.

VII

CONCLUSIONS

It has been the intent of this paper to establish the following facts:

1. That a sharp seismic impulse gives rise to a traveling *wavelet* of shape determined by the nature of the earth's absorption spectrum, and independent of the duration of the exciting impulse so long as this duration is small.
2. That a seismogram is composed of a succession of these *wavelets*, generally overlapping but sometimes in the clear.
3. That it is the center of a *wavelet* which travels with a velocity characteristic of the medium.
4. That the breadth of a given *wavelet* increases with increasing propagation time in accord with a definite law.

It is to be hoped that the above facts established by this study may aid in the problem of breaking down complicated seismograms into their component *wavelets* so that more information relative to the earth's subsurface may be obtained through the measurement of more quantities of a seismogram.

THE TIME DELAY OF A WAVE GROUP IN THE WEATHERED LAYER*

ALFRED WOLF†

ABSTRACT

Ground motion observed in seismic prospecting can be regarded as being composed of groups of waves of some predominant frequency. The velocity of propagation of such wave groups in the earth is the group velocity. A detailed application is made to the calculation of the time delay of a reflection wave group passing through the weathered layer. It appears that the weathering time of a reflection is a function of its frequency, and that it may differ from the weathering time of first arrival waves.

Examination of reflection records shows that they are composed of a number of wave groups of appreciable length. Since the impulse in the shot hole is of very short duration, the reason for the observed character of reflections must be the dispersion and absorption of elastic waves in the earth. Both of these factors are due to the properties of the material of which the rocks are made up, and also to the stratification of the upper portion of the earth's crust. If the time delay of a wave group in some layer is to be determined, the appropriate value of velocity of propagation to be used in this connection is the group velocity which, in a dispersive medium, is a function of frequency.

A great deal of work on wave propagation and group velocity can be found in the literature.[1] The nature of the problem is the following: Suppose that the phase velocity of harmonic waves in a medium has been determined experimentally or theoretically; it is desired to calculate the rate of propagation of an isolated group of waves in which a certain frequency predominates. Such a group can be described analytically as a Fourier integral over some band of frequencies. An example of a group with a predominant frequency of approximately 50 cycles per second is shown in Fig. 1, its spectrum as a function of frequency in Fig. 2. In a dispersive medium, the velocity of propagation of such a group may differ materially from the phase velocity of the predominant frequency and from the velocity of propagation of wavefronts and other discontinuities. In general, it can be stated that group

* Presented at the Annual Meeting, Chicago, April 9, 1940.

† Geophysical Research Corporation, Tulsa, Oklahoma.

[1] Cf. T. H. Havelock: The Propagation of Disturbances in Dispersive Media, Cambridge University Press, 1914.

velocity is the rate of propagation of energy; it is one of the most important parameters associated with wave propagation.

Similar considerations can be applied to the problem of time delay

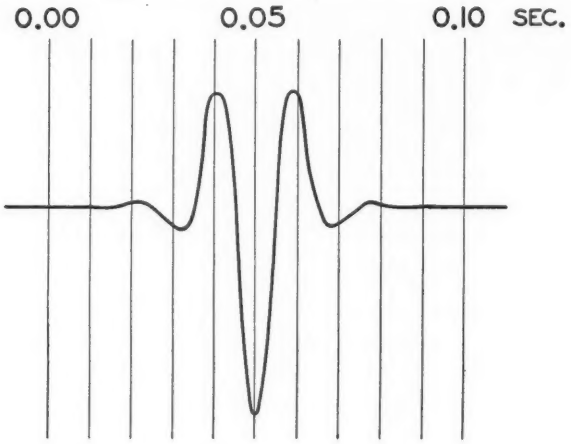


FIG. 1. Example of wave group.

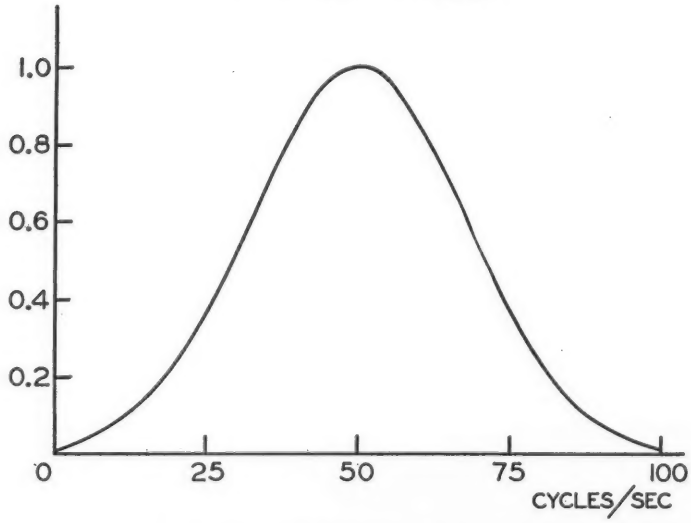


FIG. 2. Frequency spectrum of wave group.

of response of instruments under the action of periodic forces; also, to the determination of weathering time of a group of waves such as a reflection. It is the latter which will be considered in detail in the fol-

lowing. It will be shown that, under suitable conditions, the weathering time of a group may be quite different from weathering calculated from the travel time of first-arrival waves. For, the time of first breaks on a geophone record corresponds to the arrival of waves of high frequency, of the order of 100 cycles per second, whereas the predominant frequency of reflections is only 40–60 cycles per second. A difference in the group velocity for these frequencies will, therefore, produce a difference in the time delay of the corresponding waves passing through the weathered layer.

1. GENERAL THEORY OF TIME DELAY OF WAVE GROUPS

The general theory of the variation of time delay with frequency is quite simple. Let a plane harmonic wave of a certain frequency be generated at some depth underground, and let the phase retardation of the motion of the ground at the surface be plotted as a function of frequency. It is desired to determine from such a plot the delay of a group of waves in reaching the surface of the ground. When the shape of the group is known, the problem can be solved exactly by means of Fourier integrals, but such a procedure is complicated; results obtained in the related field of group velocity in dispersive media can be applied here to some advantage even though they furnish only an approximate value of delay.

Suppose first, that the phase retardation ϕ is a linear function of the frequency f, and that ϕ is zero for the frequency zero. Then

$$d\phi/d\omega = \tau \qquad (\omega = 2\pi f) \tag{1}$$

is a constant, and represents the time delay of any wave reaching the surface of the ground, regardless of the shape of the wave. When the above assumptions are not fulfilled, a wave will be not only retarded but distorted as well.

If $d\phi/d\omega$ approaches a definite limit for infinite frequency, that limit represents the time delay of a wave front in reaching the surface of the ground, and also the delay of a group of waves of very high frequency.

In the general case, τ, as defined by Equation (1), is a function of frequency. If a group of waves has one predominant frequency, τ evaluated for it is a good approximation to the true value of the time delay of the group. This should be particularly applicable to the usual reflection records taken with the aid of filters which limit the frequency band recorded.

2. WEATHERED LAYER OF UNIFORM VELOCITY

These considerations will now be applied to the case of a weathered layer of uniform velocity v and thickness a overlying a medium of velocity V (Fig. 3). Denote:

$$V/v = k > 1 \qquad a/v = T.$$

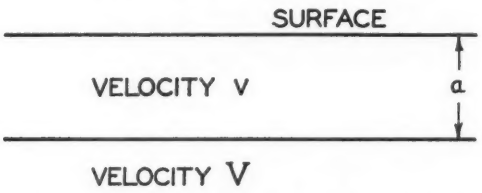


FIG. 3. Diagram of a layer of uniform velocity.

The phase retardation of an harmonic wave of frequency f arriving from below can be determined from the equation

$$\tan \phi = \frac{1}{k} \tan \omega T; \qquad (\omega = 2\pi f). \tag{2}$$

The time delay of a group of waves can be calculated easily from (1) and (2), and is given by

$$\tau = \frac{kT}{k^2 \cos^2 \omega T + \sin^2 \omega T}. \tag{3}$$

It follows that the group delay varies between the limits T/k and kT. The delay kT is attained for

$$f \cdot T = 1/4, 3/4, \cdots$$

when the amplitude of the wave reaches its maximum value. The fact that group delay defined by Equation (1) becomes T/k for certain frequencies makes evident the limitations of the group velocity method, since a wave group cannot pass through the layer in a time shorter than that of a wave front.

The following numerical example may serve for illustration. Let the thickness of the weathered layer be 10 ft., the velocity in it 2000 ft/sec., and let the velocity below the weathered layer be taken as 6000 ft/sec. The time delay of a wave front in such a layer will be 0.005 sec.; the delay of a wave group of frequency 100 cycles/sec. will be approximately the same, whereas the retardation of a group of 50 cycles/sec. will be much greater, namely, 0.015 sec. The conditions here assumed are quite extreme and not likely to occur under field

conditions where velocity changes are apt to be gradual. The calculation of time delay for the condition of linear increase of velocity with depth in a layer will be taken up in the next section.

3. WEATHERED LAYER WITH A LINEAR INCREASE OF VELOCITY WITH DEPTH

Let the velocity in the weathered layer of thickness a (cf. Fig. 4) be a linear function of the depth z

$$\frac{V}{k}\left(1+\frac{k-1}{a}z\right)$$

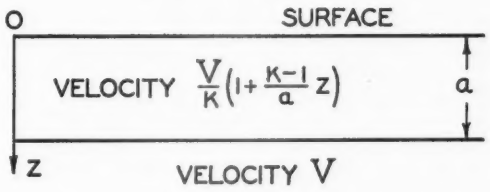


FIG. 4. Diagram of a layer with a gradual increase of velocity with depth.

so that the velocity at the surface is V/k, and the time taken by a wave front to go across the weathered layer is given by

$$T=\frac{ka}{V}\cdot\frac{\log k}{k-1}\cdot \tag{4}$$

The group delay of a wave of predominant frequency f is given by[2]

$$\tau=\frac{T}{\log k}\cdot\frac{\cosh(2\gamma\log k)-1+\frac{1}{2\gamma}\sinh(2\gamma\log k)-4u^2\log k}{\cosh(2\gamma\log k)+2\gamma\sinh(2\gamma\log k)-4u^2}\cdot \tag{5}$$

With

$$u=\frac{2\pi fT}{\log k},\qquad \gamma^2=1/4-u^2.$$

Equation (5) shows that the delay of a wave group in a weathered layer, in which the velocity is a continuously increasing function of depth, increases from zero frequency, and then oscillates with a gradu-

[2] Equation (5) can be derived from the solution of the equation of wave propagation in a medium in which the velocity is a linear function of depth. Cf. GEOPHYSICS, Vol. 2, 1937, p. 357.

ally diminishing amplitude about the delay corresponding to infinite frequency. As in the case of the layer of uniform velocity, only those time delays have a physical meaning which are greater than the time of travel of a wave front passing through the layer.

Fig. 5 shows $y=t/T$ as a function of $x=fT$ for the case $k=3$. It is seen that y increases from the minimum value 0.607 for zero frequency to a maximum of 1.36 which it attains for $x=0.37$, and then oscillates

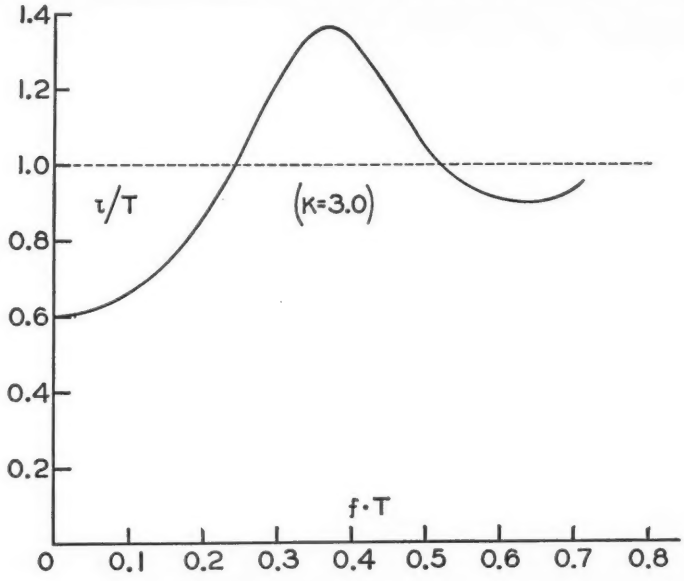


FIG. 5. Group delay in a layer of variable velocity.

with a rapidly diminishing amplitude about the value $y=1.0$. Physical significance can be attached only to values of delay above the dotted line. If the assumption is made: $a=30$ ft., $V=6000$ ft/sec., $k=3.0$, the differences in the delay of wave groups of various frequencies will not exceed 0.005 sec. in this case.

It is well known that, near the surface of the earth, velocity is a complicated function of depth which cannot be represented by either of the above simplified streatments. These examples do, however, illustrate the fact that differential weathering calculated from first breaks will not be exactly the same as the time differences calculated from reflections. For, the weathered layer has not the same thickness under all geophone locations, and consequently the time differences between the wave front and the reflection are not the same for all of them.

SHOT HOLE CHARACTERISTICS IN REFLECTION SEISMOLOGY*

H. J. McCREADY†

ABSTRACT

The influence of shot-hole characteristics on seismograms is discussed in some detail. Modifications in the formations surrounding the shot-hole caused by successive shots result in compaction or aeration affecting changes in delay times as well as changes in character of the recorded events. The importance of considering these effects in the interpretation of seismograph records and some methods of alleviating these problems by suitable field technique are discussed.

The complete "set-up" used in seismic prospecting to obtain a seismogram at any certain point, consists of two basic units; the shot point and the recording point. What character will be shown on the seismograms obtained depends upon the physical constants of the media and instruments encountered by the seismic waves in their total path. The total path of any given reflection is defined by the limits of the instance of the shot as the beginning and the instance of the impression of the first energy impulse of that reflection on the seismogram as the end. The reflection is the impression of the subsequent motion of the ground and geophonic reaction. That is to say, the character of a seismogram will depend upon:

1. The nature of the seismic waves propagated from the shot as the origin. (Wave pattern, intensity, etc.)

2. The physical characteristics of the media through which the seismic waves pass in their path from shot-point to detectors.

3. The distance intervals between the reflecting horizons, the amount of dip of the beds, and character of deformations present as faults, unconformities, folds, etc.

4. The instrumental constants of the recording channels.

The last three conditions have been given a great deal of attention in seismological literature so this paper will confine its considerations to "shot-point characteristics."

When a charge of dynamite is set off in the bottom of a shot-hole, the shot-hole undergoes a physical change which may vary over a wide range. In clay holes there usually is a packing of the clay at the

* Presented at the Annual Meeting, Chicago, April 9, 1940.

† Mott-Smith Corporation, Houston, Texas.

bottom of the shot-hole so that a "pot" is formed. This pot is determined in form by the amount of the charge and the anisotropy and heterogeneity of the surrounding formations. Assuming spherical packing of the charge, the ideal limit of the shape of this pot is obtained in an isotropic homogeneous medium. It is a sphere with the origin of the explosion as its center. The size of the pot is a function of the intensity of the explosion and the plasticity of the surrounding formation. There is no potting in a sand hole but there is a tendency for the hole to fill up because of flowage of the loosened sand. Clay holes are usually preferred to sand holes since a clay hole can be shot more times without losing depth, and usually has a greater energy transmission ratio than sand holes. In quartzitic or caliche holes, the area surrounding the explosion is cracked (probably radially), crushed and only slightly compressed.

The first shot in a hole gives rise to seismic waves propagated with a velocity depending upon the density and Lame's coefficients of the surrounding formation. The velocity is given by

$$v_1 = \left(\frac{k + \frac{4n}{3}}{p} \right)^{1/2}$$

where v_1 is the velocity of the longitudinal wave, k is the bulk modulus, n is the coefficient of rigidity and p is the density. There is no appreciable time delay of wave propagation since the charge is packed into intimate contact with the unaffected wall "facing" and if not, the wave path between the explosion and surrounding formation is so short that any time delay will be negligible. After the first shot the character of the hole is changed by the immediate effects of the explosion. The two features of the shot-hole which are affected are:

1. The size of the bottom of the hole.
2. The physical properties of the hole facing and surrounding area.

These two features vary greatly with the physical properties of the confining media. The size of the bottom of the hole may vary from a large cavity or pot in soft clay to a comparatively unchanged hole in a hard sandstone. The facing may be broken and crushed, compacted or unchanged. Density, Lame's coefficients, Young's modulus, and the specific acoustic resistance also vary.

After the first shot the shot-hole is filled with a fluid mud-gas mixture, and if the facing is fissured the cracks will be filled by a

part of this fluid. If the formation is highly porous there will also be a partial filling of the interstices for a short distance. The area of aeration about the shot-hole is that portion of the surrounding media physically changed by the explosion. In the case of potted holes, total aeration will also include tamping fluid through which the waves must pass. The seismic waves emanating from subsequent shots experience a time delay because of the low wave-propagation velocity of the media constituting the area of aeration. Not only does this aeration result in a time delay, but there is often a deviation in character between seismograms from the same shot-point.

The practical aspects of aeration might be clarified by considering seismograms from affected shot-holes. The first feature, as already noted, is the time delay. Any single reflection will have an arrival time on any record greater than the arrival time of the same reflection on preceding records at the same shot-hole. This will be true (within certain limits) in that the amount of aeration increases with each shot. On actual seismograms there appears to be a limit at which no more aeration results from further moderately small charges. The limits of aeration are complex functions of the composition of the shot-hole formation, extent of induration of the sediments, and size of the charge used. Keeping the size of the charge constant a gradational decrease in the limit of aeration may be noted going north from the coast line of Texas and Louisiana. For example, time delays (using 1 to $2\frac{1}{2}$ pound charges and the third or fourth shot in the hole as a datum) up to .010 sec. are experienced near the coast, but near the Texas-Oklahoma line the limit is about .003 sec. In the blue clay holes of northern Texas there is evidence of numerous instances of minus aeration (as much as .002 sec.). This decrease in the reflection arrival time is probably due to an increase in the wave propagation velocity of the bottom hole formation. With each shot the clay is compacted so that both density and Lame's coefficients are increased. The increase in density is small compared to the increase in the Lame's coefficients resulting in an increase in velocity. The amount of aeration upward from the location of the explosion is greater than downward as shown by comparing the arrival time of the direct wave to a shotpoint geophone and the arrival times of the reflected waves to the spread geophones. This greater aeration is, in part, the result of the direct wave passing through the mud-explosive gas mixture above the charge. The outcome of this last consideration is that a special aeration correction must be made for computing

weathering by use of a shotpoint geophone. This correction need be applied only when using a record other than the first one of the hole.

The conclusion is that the later records of any shot-point should be corrected to the first record of that shot-point. To calculate this correction the arrival times of several energy bands are determined on the first record and the arrival times of the corresponding impulses are determined on the record or records to be used for correlation. An average time difference is taken for the entire record to be used and this average time difference or aeration correction is subtracted from the arrival time of each reflection used in depth computations. if more than one record is needed for the correlation then a separate aeration correction must be made for each of the records. At many shot-points the first record will often be "unreadable," so it is suggested that the second record be used as the datum record. No serious errors will result as long as the first and second charges are kept at a small amount throughout the survey. An alternate datum record can often be used by referring the records back to the first record from a certain given small charge which does not result in an appreciable time delay. It is important that corrected records are taken at, or corrected to, the same depth as the datum record. The first record at a new depth will have an aeration correction plus a depth correction, both of which may be combined into one total aeration correction and the depth of the datum record used in the computations.

A second feature deduced from affected seismograms is: the interference pattern of an energy band may be altered because of phase shift. This change may be exceedingly disconcerting in correlating seismograms since the basic feature of correlation is the comparing of character of energy bands and time intervals of single and multiple reflections between records from shot-point to shot-point. An energy band consists of two or more reflections arriving in conjunction with one another so as to give a certain definitive "appearance" or character to the seismogram. This character is outlined by phase changes resulting from the imposition of the first arrival of energy of a reflection upon the wave form of a reflection immediately preceding it. Since the two reflections will rarely be in phase the wave form of the energy band will show a transition from the first reflection to the second. Thus character transformations between records at the same shot-hole make correlation confusing and the real first impulses of energy are often obscured. The character of the phase change is

varied by phase shift. This phase shift is caused, in part, by the time delay suffered by the seismic waves passing through the area of aeration. Also, the area of aeration has a low specific acoustic resistance so that a seismic wave passing through this area into an area of higher specific acoustic resistance undergoes a phase shift depending upon the amount of variation of the specific acoustic resistance in the area of aeration with each subsequent shot. The character of single energy impulses are changed in a similar manner.

Character in a simple reflection is demonstrated by two conditions:

1. Onset conditions (phase change).
2. Development of the wave-form.

The onset conditions of a reflection includes all the energy impulses present at the time of arrival of the first energy impulse of the reflection. It also includes the manner of arrival of the reflection such as whether it is a rarefaction or compression wave and the emergence angle of the wave. The energy impulses present may be either from reflected waves, stray subsurface waves (from fault planes, etc.), groundroll, and such outside disturbances as a.c. pickup, wind, rain, and airwave. Some of the variations in the onset conditions will also be a result of variations in instrumental settings.

The development of the wave form of an energy band or single reflection consists of the "graphical appearance" of the wave form with regard to amplitude and frequency variations. This feature may be used for a comparative study between records at the same shot-point in an attempt to obtain the best record possible at that shot-point. Amplitude is one of the important factors to control in obtaining a record. At some shot points a low amplitude record will show a more definitive character and at other shot points the high or medium amplitude records are best. A balanced record obtained by using an expander or automatic volume control facilitates correlating but care must be taken that weak reflections are not overemphasized. With the use of such instruments weak reflections may be made to appear equally important with respect to the strong reflections by increasing the amplitudes of the former and decreasing the amplitudes of the latter to a constant current input-level. Thus weak inconsistent reflections would only confuse correlating. A comparison of wave development between records at the same shot-point will also aid in making the best time picks for dip calculations and aeration corrections. In picking times for dip and depth calculations it is important to mark as close to the first impulse of the reflection as possible with-

out selecting a rounded or obscured peak or trough. By making the time-picks near the beginning of the reflection, errors from frequency variations within the reflection are also eliminated.

Several factors affect the natural development of a wave form and must be considered in order to analyze the true first-arrival of energy. These factors include:

1) Resonance,
2) Roll,
3) Frequency variations,
4) Amplitude inversions,
5) Air wave,
6) External disturbances.

The sixth factor includes wave variations resulting from energy impulses caused by induced alternating current, loose connections, nearby bodies in motion, etc. The other five factors are, to a great extent, shot-hole characteristics.

Resonance is evidenced on a seismogram by a sinusoidal wave form with very few apparent phase changes and very little damping (much "tailing" of each reflection). The record takes on the appearance of an alternating current wave varying in amplitude and having the frequency of the reflections. In some cases small charges give rise to resonance, since there is less amplitude discrimination and the phase changes slur resulting in smooth sinusoidal waves. In such cases phase change positions may often be detected by an increase in amplitude and by frequency changes. Most reflections have a frequency ranging between 40 and 60 cycles per second, while the frequency of a distinct phase change is around 80 to 100 c.p.s. If the phase change is slurred then the wave form at this point may have a frequency of 40 c.p.s. or less. The solution for this form of resonance is to use larger shots. A larger shot gives a better discrimination between reflections by sharpening phase changes. The amount of increase of the shot is limited by the introduction of "roll." In some instances an apparent resonance is the result of induced alternating current with a frequency of 60 c.p.s.

Resonance may also be caused by an in-phase condition between the recording-position formation or the shot-hole formation with respect to the reflection frequency or a combination of both. Also there may exist an in-phase relationship between the reflecting horizons themselves. In these cases a larger shot will only accentuate the resonance of the record. However, if the charge is shot at a different

depth the resonance is oftentimes eliminated to a great extent. This is not infallible because the resonance may also be increased by shooting at a different depth.

A third type of resonance arises from multiple energy impulses arriving at very short time intervals. Such may be the case in the presence of lenses or a succession of thin beds. As a problem of a shot-hole characteristic these multiple energy impulses may also result from shooting too far below a certain surface layer, usually the base of weathering. The energy from a shot travels in all directions and certain of these waves passing upward may be reflected downward from the base of weathering, thereby giving rise to a new wave train of energy. This secondary reflected energy will lag the energy travelling directly downward by a small amount. The effect on the character of the seismogram will be to increase the duration of simple reflections and to interfere with the wave form of energy bands. Such records show not only resonance but false phase changes. A solution may be effected by varying the depth of shooting.

Resonance is undesirable in correlation because the first energy impulses of reflections are masked by phase change slurs, there is a lack of discrimination between reflections, and there is little comparable character between records at different shot-holes.

In this paper "roll" is distinguished from "groundroll" in that groundroll is a complex low frequency wave traveling along the surface of the ground, and roll is an apparent character due to a rounding off of the peaks and troughs of a wave form and the presence of low frequency reflections. The charges at a shot-hole may be increased to a certain limit within which the wave form is varied chiefly through an increased intensity of energy. Beyond that limit the record undergoes a complete change in character. The inflection points of the wave form are rounded off or slurred, the average frequency of the record is decreased and the whole has a "chopped-up" appearance. This roll is likely to occur with relatively small charges when the subsurface formations are badly broken up as by faulting. Records from large charges indicate that energy from such shots has a frequency much lower than that from small charges. Similarly, the sound waves heard by a person at the shot-point have a much lower pitch when arising from a large shot than those from a small shot. Records showing much roll are difficult to correlate since they show so little consistent character and it is also difficult to pick arrival times with much accuracy.

In most instances the frequency of a reflection decreases towards the tail of the reflection. In some areas this decrease in frequency may become greater with larger shots and the amplitude decay may also be increased. The frequency of an average reflection depends upon the physical constants of the formations and instruments as filters. When the shot-hole formation is hard and resistent the reflection frequencies are usually much higher than when the formation is friable or plastic. In both instances the frequency of a reflection will be decreased by using moderately large charges. Unless the arrival times of a certain reflection is being picked at the phase change there will be a time lag on later records at the same shot-point (compared to the first record) because of decreasing reflection frequency with increasing charges. In some areas this time lag is of sufficient magnitude to need correcting.

A study of wave development includes a comparison of the amplitudes of the peak and trough of each cycle in the reflection. A strong reflection will show a consistent character or relationship between the amplitudes of each cycle but even these relationships can be varied and inverted by varying the size of the charge. The greatest energy input may be indicated by the high amplitude of the first trough, for example, but after several shots the physical properties of the shot-hole formation may be so changed that the second peak of the reflection will show the greatest amplitude. With this retardation of the greatest energy input the character of the reflection is changed and may, consequently, obscure the true position of the first arrival of energy. As a result the phase position of a reflection may be miscorrelated by one or two cycles.

When the charge is set off a sound wave is generated in the air and is propagated parallel to the surface of the ground. If the geophones are so spaced from the shot-point that the air wave hits the tops of the geophones during the time of recording, a disturbance is impressed upon the normal wave form at the time of arrival of this sound wave. The arrival times of this wave give the appearance of a refracted wave except that the sound wave has a much higher frequency. This disturbance is usually termed air wave or blastophone. Whether a record will pick up the sound wave depends not only upon the proximity of the spread to the shot-hole but also the intensity of the sound emitted, and the intensity is dependent upon the size of the charge, its tamping and absorption factors of the shot-hole formation.

The presentation of this paper has been based upon the results of an investigation of records from a number of surveys, but there are certain physical conditions inherent in all areas and are usually considered as a matter of theoretical interest. The area of aeration is heterogeneous and anisotropic so that waves passing through this area are affected by the following.

1. Variations in the specific acoustic resistance.
2. Spreading of energy by dispersion, selective scattering, and geometric divergence.
3. Dissipation of energy.
4. Absorption of energy because of heterogeneity and plasticity.
5. Internal reflection and refraction resulting in a partitioning of energy and amplitudes of the seismic waves.

Formational conditions affect the comparative energy transmission between shots. In most sand holes the bottom-hole formation is moderately indurated and has elastic constants favorable to wave propagation. After a few shots the sand is loosened and the formation is fissured resulting in a low energy transmission area. The hole becomes "dead" and the records lose all definitive character. In many clay holes the first shot shows a smaller energy transmission compared to later shots. The energy from the explosion is used up overcoming the plasticity of the clay. After the clay is compacted the energy is transmitted more completely.

In summary, the paper has presented features affecting the type and quality of character of seismograms. It is the writer's opinion that a quantitative study of seismograms will be more informative if a qualitative study is first made to eliminate the effects introduced at the shot-hole.

MICHIGAN WEATHERING*

N. N. ZIRBEL†

ABSTRACT

In this paper the weathering conditions found in the Michigan Basin are discussed. It is shown that the depth of the drift cannot generally be determined from weathering profiles and a method for correcting reflection depths under these conditions is suggested.

The sedimentary beds in the Michigan Basin are overlain by a mantle of glacial drift ranging from 50 feet in thickness at the extreme edges to over 800 feet in the central parts. In general the drift can be divided into two layers with respect to its seismic reactions: (1) A layer of unconsolidated topsoil above the water table (2) A more consolidated and water saturated layer below the water table

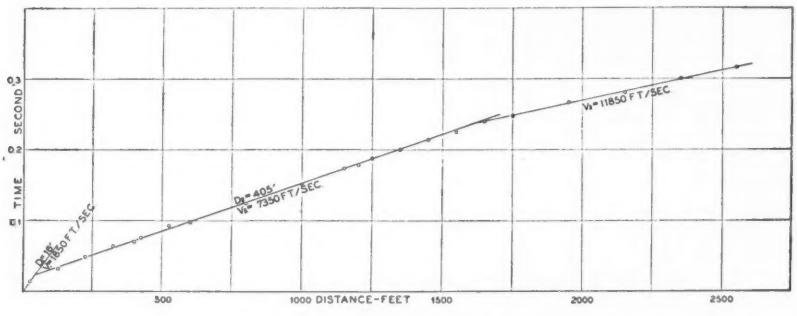


FIG. 1. Typical Weathering Profile—Michigan.

Short refraction profiles known as weathering profiles are taken at each shot and recorder location of a seismograph survey in order to measure the velocity and thickness of the materials near the surface. Fig. 1 shows the results of such a profile taken in the Michigan Basin. In this graph the distance from the shot to the geophone is plotted horizontally and the time of arrival of the first refracted wave vertically, so that the slope of the line gives the velocity of the wave front travelling along the surface. From these graphs the thickness and velocity of the materials penetrated by the refracted wave can be calculated.

* Presented at the Annual Meeting, Chicago, April 11, 1940.

† Independent Exploration Co., Houston, Texas.

In general these weathering profiles have shown three layers:

(1) A layer of topsoil in which the velocity ranges from about 1000 to 3000 ft. per second. The thickness of this layer varies over a wide range, but in general the greatest thickness is observed on hills, the base of the layer approximately following the water table. This is probably the aerated portion of the drift or the true "weathered zone."

(2) A layer in which the velocity ranges from about 5000 to 8000 ft. per second, the great majority of these velocities being in the neighborhood of 7000 ft. per second.

(3) A layer in which the velocity ranges from 10,000 to 12,000 ft. per second. At isolated points this velocity has been observed as low as 8000 ft. per second and as high as 15,000 ft. per second, but such variations are rare.

At first inspection of the above data it would appear that the first and second layers could be interpreted as the glacial drift and the third layer as the top of the sedimentary beds but the following data has shown that this is not the case.

(1) Well shooting has shown the average velocity in the sedimentary beds immediately below the drift to be the same order of magnitude as the velocity in the lower part of the drift and much lower than the third velocity found on the weathering profiles.

(2) Comparison of the depths of the third layer with well logs has shown no relation between the thickness of the drift and the depth of the third layer on the weathering profiles other than the fact that the third layer on the weathering profiles was always below the drift. In areas where good well control was available the third layer has been observed to range from 0 to 400 feet below the base of the drift.

(3) Well logs show the section below the drift to be sands, clays, and soft shales with relatively thin lenticular limestone and sandstone beds scattered through it.

From this data it appears that the general weathering conditions in the Michigan Basin are such as are shown in Fig. 2, that is:

(1) A layer of aerated topsoil in which the velocity averages about 2000 ft. per second.

(2) The more consolidated and water saturated part of the drift in which the velocity averages about 7000 ft. per second.

(3) The sedimentary beds, composed of sands, clays, and shales in which the velocity is the same order of magnitude as that in the lower part of the drift, and relatively thin lenticular beds in which

the velocity ranges from 10,000 to 12,000 ft. per second, these lenticular beds being at various depths in the sedimentary section.

Under these conditions the depth of the third layer on a weathering profile will be the depth of the first of these lenticular high velocity beds at that particular location and the mapping of the first of such beds will give no indication of the configuration of the top of the sedimentary section.

Since the data obtained so far indicates the third velocity layer on the weathering profiles to be from relatively thin lenticular high

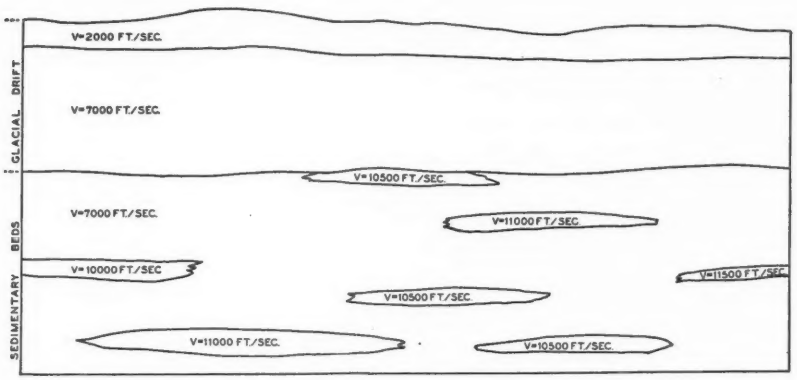


FIG. 2. General near-surface conditions in the Michigan Basin.

velocity beds at varying depths in a section in which the average velocity is the same order of magnitude as the velocity in the second layer, it is believed that the correction of reflection depths to this third velocity layer would give an incorrect structural picture.

If the base of the first layer is fairly level or subject only to a regional slope it is believed to be necessary to correct for the layer of low velocity topsoil only.

If the base of the first layer is rugged (hills or valleys of 50 feet and over) it would probably be better to select a horizontal reference plane about 100 feet below the base of this layer and assume the velocity in the section between this plane and the base of the low velocity layer to be the average velocity of the second layer in the area. This section should then be treated as a second weathered layer and the usual corrections for two layer weathering applied.

SEISMIC REFRACTION STUDIES IN THE ORINOCO BASIN OF DEPOSITION, VENEZUELA*

M. KAMEN-KAYE†

ABSTRACT

The progress of seismic refraction methods in the Orinoco embayment is briefly sketched. Uniformity of post-basement velocities and relations to compaction are noted, unusual velocities being analyzed. The author's use of flexure-time contours is described and the effect of basement velocity variation on flexure time is presented empirically.

Seismic refraction measurements have been made in Venezuela for approximately a decade. Their first appearance in the Orinoco sedimentary basin was perhaps some three or four years before reflection methods were commercially applied even in the States. However, even had the reflection method been available earlier, it is probable that refraction would have held the field in the first stages of broad reconnaissance.

The geologists in charge of exploration had assumed that the igneous-quartzite complex which outcropped along the Orinoco river must provide important subsurface traps under the plains farther to the north. They had assumed that the sloping basement of presumably ancient rocks must be overlapped by sediments in a manner that would yield shore lines in some cases, depositional structures over nuclear prominences in other cases and possibly gentle contemporaneous folds in which basement and overlying sediment might both be involved. With regard to geophysical conditions, a favourably large differential was to be expected in the difference of density and other physical properties between basement rock and overlying sediments.

Actual results proved that there was a great expanse of territory in which refraction shooting provided a clear-cut reconnaissance method. Thus within less than two years, traverse cross-sections were made out into the Orinoco basin at localities as far east as the Orinoco delta and as far West as the Colombian border facing the Venezuelan Andes.

The marked high-speed flexure which was obtained on the majority of plotted time-distance graphs provided a seismic event capable of correlation with a great degree of security. Earlier investigators analyzed horizontal velocities above basement and attempted to cor-

* Manuscript received December 27, 1939.

† Caracas Petroleum Corporation, Apartado 89, Caracas, Venezuela, S. A.

relate the various discontinuities which each plotted graph showed. With more study however, it became apparent that in the strata above basement, differentiation was comparatively poor. Under such depositional conditions, time-distance curves for the stratified overburden approximated to continuous functions either of parabolic or hyperbolic form in contrast with discontinuous functions.

In the writer's particular experience, it has been noted that

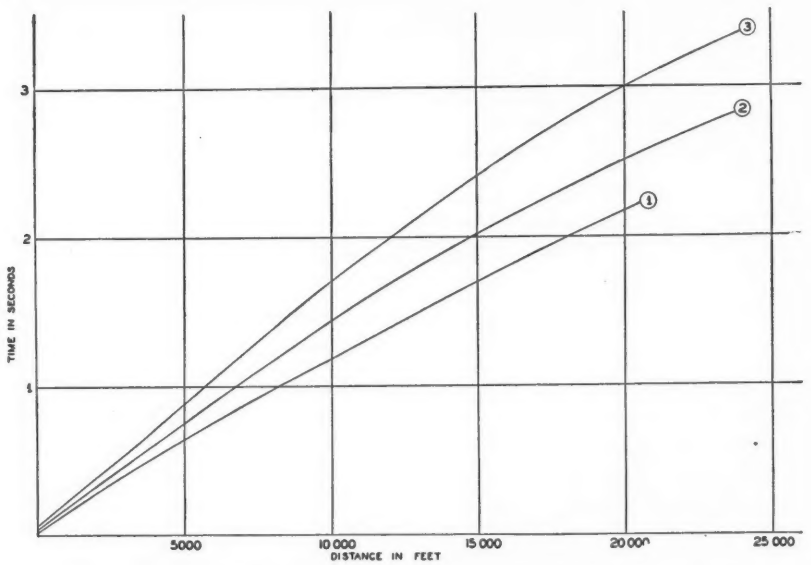


FIG. 1. Time-distance curves showing sedimentary velocity characteristics.
Distance between curves 1 and 2 is 50 miles.
Distance between curves 2 and 3 is 200 miles.

velocities above basement are practically confined to a band whose lower limit is 6000 feet per second and whose upper limit is rarely more than 10,000 feet per second. This band of velocities has been found in areas as much as two hundred miles apart, so that physical uniformity of the post-basement strata could be deduced as a regional feature. This relative increase of velocity with depth of sedimentation over wide areas suggests that compaction has played an important part in giving the Orinoco basin strata their general geophysical uniformity. In Fig. 1, the post-basement velocity groups are illustrated by field time-distance curves brought together in a single diagram.

It is evident that compaction must be less where the column of

post-basement strata is thin, and greater where the column is thick. Therefore the final velocity of the column where it rests on basement must be roughly proportional to the depth of the basement. This point is illustrated in Fig. 2 with curves taken from widely separated profiles. Depth relations are also shown.

With results such as those illustrated in Fig. 2, a "normal" framework of velocity-depth relationships can be drawn up. Velocities which do not conform to this framework, especially those velocities which

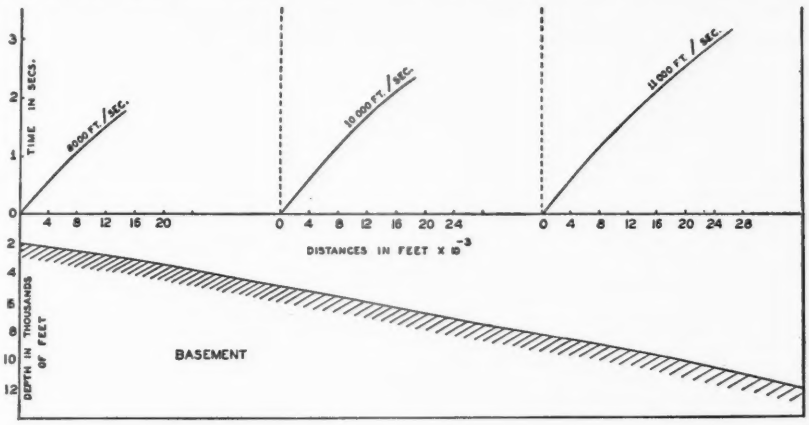

TIME IN SECS.
8000 FT./SEC.
10 000 FT./SEC.
11 000 FT./SEC.
0 4 8 12 16 20
0 4 8 12 16 20 24
0 4 8 12 16 20 24 28
DISTANCES IN FEET X 10⁻³
DEPTH IN THOUSANDS OF FEET
BASEMENT

FIG. 2. Final velocities above basement from field profiles, together with depth relationships.

seem too high for the depth of the profile, are likely to be special structural cases. They should, in fact, be used as diagnostic features in searching for anomalies rather than be accepted as local velocity "injections."

In particular, two types of "abnormal" velocity occur. They are

(a) Apparently high post-basement velocities which in reality are basement velocities obtained when shooting down sharp changes of basement slope.

(b) Apparently low basement velocities which in reality are post-basement velocities augmented when shooting up dip.

These two types are illustrated in Fig. 3. In the type (a), an abnormal velocity is shown in what is apparently the post-basement part of the curve. Actually, the relation of profile to basement is that of a straddle across dip changes such as is shown in the cross section which corresponds to the curve. An abnormal velocity of type (b) is shown

in what is apparently the basement part of the curve. At first glance a faulted basement would be read into the curve. The actual condition as given by surrounding profiles, shows that the abnormal velocity is the quickest path up-dip on post-basement material until increase of spread brings in the true basement as first break. This latter interpretation is further supported by the fact that the two high speed curves in the (b) type of profile have a common distance where one

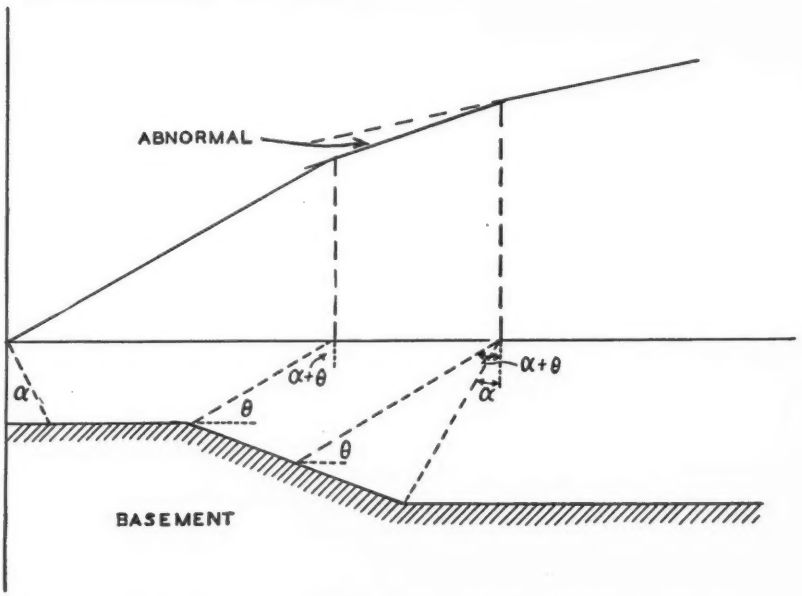


FIG. 3a. Diagrammatic sketch of abnormal velocity. Apparently high sedimentary velocity is actually down-dip velocity on basement.

curve terminates and the other begins almost simultaneously. This condition would be theoretically possible for a clean vertical fault, but natural faults rarely fulfil such conditions. It is also possible that the (b) type may arise from refractions in a plane at an angle with the vertical plane passing through the profile equal to slope of dip face or hade of fault face.

The computation of depths from a group of refraction profiles is a tedious process especially where a series of three or more horizontal velocities is taken for each profile. Such computation increases the possibility of error unless careful checking is undertaken. Assuming that the individual profiles are correctly calculated however, the cor-

relation of profiles may be misleading since the resultant high speed obtained may vary considerably from one profile to another. In those cases where questionable velocities intervene, the issue is still further complicated. These questionable velocities give greatly changed intercepts on the time ordinate and frequently confuse the correlation.

In view of these well known limitations of the methods of depth calculations in refraction, the author has made it a practice to consider

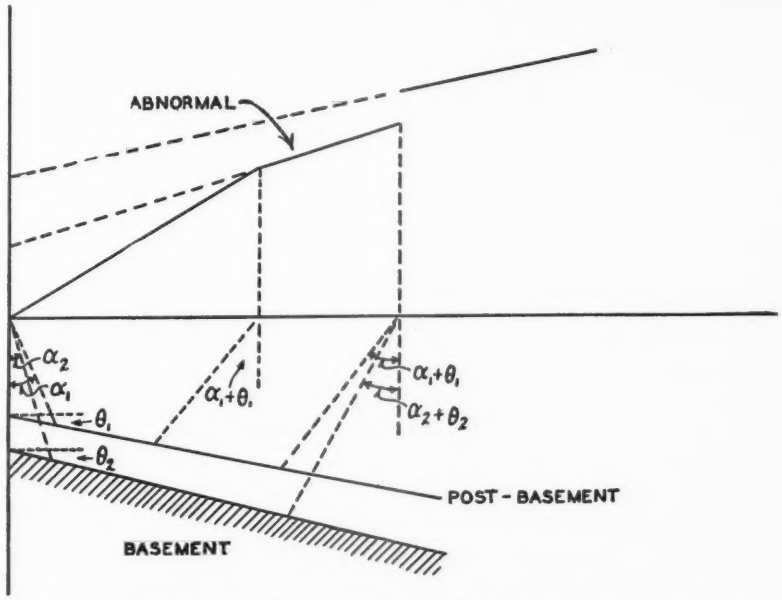


FIG. 3b. Diagrammatic sketch of abnormal velocity. Apparently low sedimentary velocity and fault effect are refractions from two distinct beds.

the fundamental quantity of time when comparing profiles. Actually a comparison is made directly between the times of high-speed flexure of a group of profiles. These times are then plotted approximately on a map and contoured, usually in tenths of a second. Since the time quantity being contoured is fundamental, the discrepancies are kept to the original proportions and presumably are not magnified by the use of derivatives such as intercept on the time ordinate.

Perhaps the greatest discrepancy which refraction correlation has to contend with is the variation of basement speed from one locality to another. Where refraction profiles are closely grouped, this variation is comparatively small but when correlation is attempted over a

wide area or province, the possible variation in basement speed becomes progressively greater.

In order to evaluate the variation of basement speed and its effect on average profiles, the following discussion is set out.

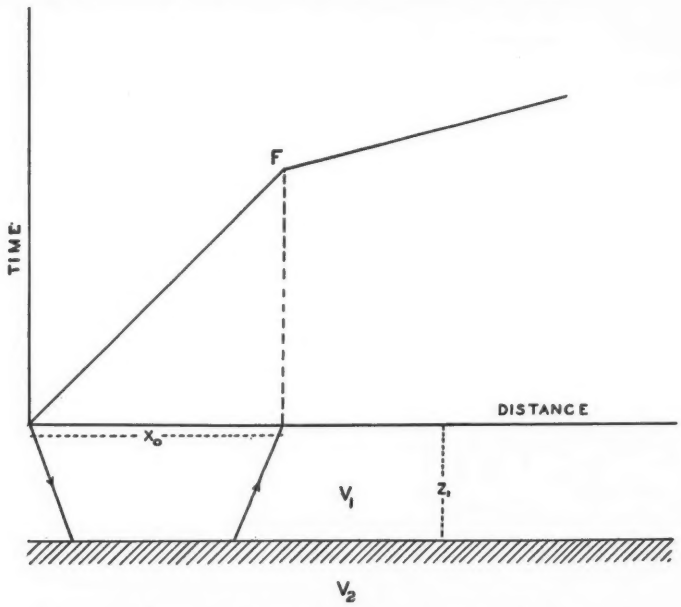


FIG. 4. Two-layer refraction profile showing point of flexure at F.

In the profile of Fig. 4, F is the point of flexure in a simple two-layer problem. By considering the time directly along x_0 and equating this to the refracted time along the interface, an expression is obtained involving α the critical angle, z_1 the depth, and x_0 the flexure distance. This expression may be written

$$x_0 = \frac{2z_1 \cos \alpha}{1 - \sin \alpha}.$$

The flexure time T_1 is then

$$\frac{x_0}{V_1} = \frac{2z_1 \cos \alpha}{V_1(1 - \sin \alpha)}$$

since $\sin \alpha = V_1/V_2$ and $\cos \alpha = \left(\frac{V_2^2 - V_1^2}{V_2^2}\right)^{1/2}$

we may substitute, simplify and obtain the flexure time

$$T_1 = \frac{2z_1}{V_1}\left(\frac{V_2 + V_1}{V_2 - V_1}\right)^{1/2}. \tag{1}$$

For discussion of the basement variation we may take the velocity V_2 as representing basement and the velocity V_1 as representing the complete overburden. If now the depth an conditions of the overburden remain constant but only the basement velocity change from V_2 to V_3, we may write (1) in the form

$$T_2 = \frac{2z_1}{V_1}\left(\frac{V_3 + V_1}{V_3 - V_1}\right)^{1/2}$$

whence

$$\frac{T_1}{T_2} = \left(\frac{V_2 + V_1}{V_2 - V_1}\cdot\frac{V_3 - V_1}{V_3 + V_1}\right)^{1/2}. \tag{2}$$

In the Orinoco basin of sedimentation, the extremes of basement speed lie at about 15,000 feet per second and at 20,000 feet per second respectively. Assuming an average velocity of the overburden to be about 8000 feet per second, we may evaluate the extremes of basement variation in an empirical manner. Thus, assuming $V_3 = 20 \times 10^3$ ft. per sec. $V_2 = 15 \times 10^3$ ft. per sec. and $V_1 = 8 \times 10^3$ ft. per sec., we may write from equation (2), the ratio of flexure times

$$\frac{T_1}{T_2} = 1.17.$$

Therefore the correlation error in reading flexure times is less than 20% for equal conditions of overburden where the variation in basement velocity may be as great as 25%. In correlations over a whole geosyncline of the Orinoco type, a simple reading of flexure times would slightly reduce the distortional effect of total basement variation.

In correlating a group of profiles within a fairly restricted area, the variation in basement velocity is likely to be less than 2000 ft. per second for the group. Assuming a 2000 ft. per second variation in basement speed, we might substitute for example in (2)

$$V_3 = 17 \times 10^3, \qquad V_2 = 15 \times 10^3, \qquad V_1 = 8 \times 10^3.$$

Then

$$\frac{T_1}{T_2} = 1.09.$$

Therefore the correlation error in reading flexure times is less than 10% for conditions of equal overburden where the variation in basement velocity is about 12%. This magnitude of error will not unduly distort anomalies of the broader type to the discovery of which refraction methods are brought to bear.

In conclusion, it might be mentioned that the flexure distance x_0 is identically affected by change in basement velocities, the relations of (2) holding for flexure distance as well as flexure time.

The author acknowledges the benefit of discussion with Professor V. C. Illing and Mr. W. R. Ransone. Thanks are due to G. R. Brotherhood who prepared this paper for publication.

THE MECHANICS OF THE UPSIDE DOWN CORE*

EDWARD D. LYNTON†

ABSTRACT

Very frequently cores taken from trays and oriented by the Herrick-Lynton method of magnetic core orientation have been wrongly marked as to top and bottom. If the bottom of the core is run as top, the resulting orientation is not 180° off unless the points of the compass are marked similarly to a Brunton Compass, namely, transposition of east and west.

INTRODUCTION

Due to the frequent submission of cores which have been erroneously marked as to their tops, it was found necessary to arrive at a method of correcting this error. Though this correction has been in use since the early days of orienting by this method, it was thought advisable to prove it experimentally. A standard core consisting of Vivianitic sandstone (Pliocene) was used in the laboratory experiments. The core was cut out in place from an exposure of this sandstone in the Kettleman Hills area. This formation was chosen because the mineral grains present are so strongly polarized as to make it an ideal core for experimental purposes. The ideal sine curves (Fig. 1, A and B) obtained from this core represent true polarity.

VIVIANITIC SANDSTONE TEST CORE

The dip and strike of the particular bed in the SW-1/4 of Sec. 21, T-22-S, R-18-W, from which this core was cut was measured in the field with a Brunton Compass by Mr. R. E. Darke of our Geological Department at Bakersfield and dip was determined to be 16° to the S.60°W.

The core was ground to a cylinder with dimensions of 3″×3″. The top, being known, was marked in the usual way, that is, the strike line through the bedding was indicated as 0°–180°, and with an arrow at 270° representing the inclination of the bedding to the right of the operator. All cores run by this method are marked in this standard manner because all original experimental work was carried on with such markings.

* Read by title, Annual Meeting, Chicago, April 11, 1940. Published by permission of the Standard Oil Company of California and Sperry-Sun Well Surveying Company.

† Petroleum Geologist, Research and Development Department, Standard Oil Company of California, Drawer 430, Whittier, California.

The core is first run by placing the top facing the operator, with 0° at the top and the inclined bedding to the right at 270°. (See diagram, Fig. 1A). The core is then revolved clockwise under the magnetic system with an air gap adjusted to give the smoothest curve. After a rotation of 360°, the core is then reversed in the holder so that the bottom faces the operator with 0° again at the top edge of the core. On reversing the core in this manner, the bedding assumes the same inclination to the right of the operator. The core is then rotated counterclockwise with the same air gap as on the previous run.

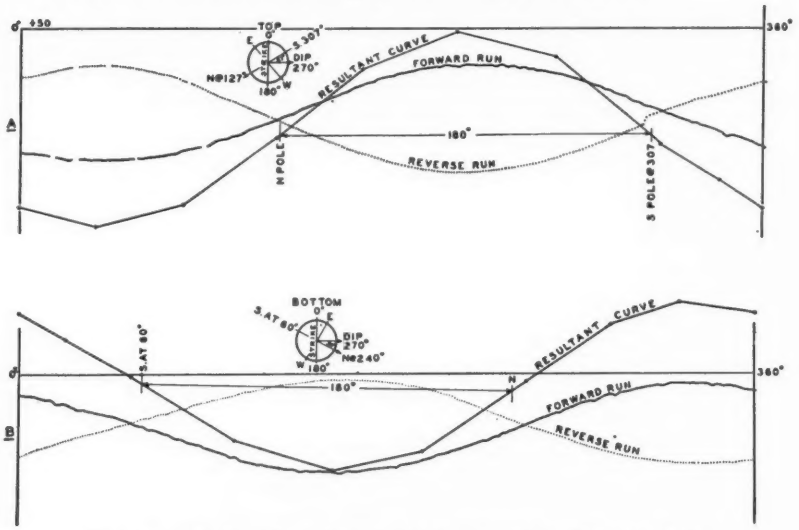


FIG. 1. *A*—Surface Core. Measured dip on surface 16° to S. 60° W. Dip by core orienter 16° to S. 54° W.

B—Surface Core. Test run on reversed core. True bottom marked as top. Measured dip on surface 16° to S. 60° W. Dip by core orienter N. 47° E. which on 180° correction becomes S. 47° W. Note that when core is reversed, E. and W. are transposed on diagram so as to leave them in same relative location as when core is in true top position.

For the sake of brevity, the curve obtained with the top facing the operator is called the "forward run" and is represented by a solid line. The curve with the bottom facing the operator is named the "reverse run" and is distinguished by a dotted line.

Fig. 1 A gives the two curves obtained by photographing the deflection of the magnetic system as the core was rotated in the forward and reverse runs. It will be noted that both curves are ideal sine waves, intersecting at points approximately 180° apart. The points of intersection represent the two poles, north and south. From experi-

mental work, the south pole is known to occur where the dotted curve, traveling downwards from right to left, crosses the solid line.

As the distance between the two intersections is not exactly 180°, because nature does not distribute its minerals perfectly, a resultant curve is drawn by graphically subtracting the reverse run (dotted line) from the forward run (solid line). The resultant points, after being joined, give an ideal sine wave. The poles are located by fitting in a 180° chord as shown in (Fig. 1 A). It will be noted that the poles are midway between the high and low points of the resultant sine wave and the south pole is always to the right of the highest point of the curve.

The scale of the curves from starting point at left-hand side to end of run is 360 on the 20 scale, which is equivalent to 360°. From zero on the left to the south pole, this distance is 307°, which is the location of the south pole on the core from the 0° mark measured counterclockwise to 307°. Referring to the diagram of the top of the core (Fig. 1 A), the arrow indicating the bedding falls at 270°. Therefore, 307°–270° gives a magnetic orientation of S. 37° W. Correcting for a magnetic declination of 17° east of north (Kettleman Hills), the true direction of dip of this core is S. 54° W. The actual measurement in the field was S. 60° W., indicating an excellent result with the magnetic core orienter.

TEST ON THE UPSIDE DOWN CORE

Assuming that this core was erroneously marked so that the bottom was marked as top: The first step is to mark the pseudo-top of the core as described above with the bedding to the right of the operator. The operator then makes his forward and reverse runs but this time he starts out with the bottom facing him on his forward or clockwise run.

After plotting the resultant curve, (Fig. 1 B), the south pole is found to occur at 60° instead of at 307° as in A. This change is entirely due to the reversed core and the markings on the bottom of the core, when run as top, and the opposite rotation ensuing because bottom is facing operator. With the conventional markings of N, S, E and W on this face, an orientation of N. 30° W. (magnetic) or N. 13° W. after correcting for declination is obtained. This result obviously does not fit the field conditions of a dip to the S. 60° W. Neither by reversing the N. 13° W. result by 180° to S. 13° E. for an upside down core is a result obtainable which will approximate the true conditions. Hence, a simple reversal of 180° applied to the orientation is

not the solution for an upside down core under these conditions.

Considering now both A and B, Fig. 1, it is obvious at a glance that B has been run on the bottom end of the core in this instance because the resultant curves are not only offset, but the high point of the sine wave on A is in opposition in a general way to the low point of the sine wave on B. Furthermore, the poles on the two plates are opposite, though offset some little distance.

In a series of three to five cores, it is easy to select the core that has been reversed. Those run with the true top will have their resultant curves coincident to within a few degrees, while the curves on the upside down cores will be offset, the poles reversed from those of the true top, and the resultant curves will have their high and low areas opposed.

CORRECTIONS ON UPSIDE DOWN CORES

Since this N. 30° W. (magnetic) orientation obtained from (Fig. 1 B) with south pole at 60° bears no relation to the field conditions, it is immediately suspected that the core has been reversed. This reasoning is applicable to any core whose top is not known for sure, but where some general knowledge of the direction of dip is surmised. In commercial work, however, such reasoning is not possible, as cores are sent in "blind," and it is the clients' responsibility to mark the correct tops on the cores themselves. The commercial laboratory in reporting the results can point out that a core in a series is obviously upside down because of the variation in the result.

In all cores run with true top as top, when once the location of north, south, east and west are established on top of the core, these points remain the same when the core is reversed except that on the reversed end or bottom, east and west assume the same position as found on reading a Brunton Compass. In other words, east and west, though they do not change on the core itself, are transposed on the core diagram or core bottom when true bottom is run as top.

By referring to the core diagram on (Fig. 1 B) ,where the bottom of the core was run as top, it will be noticed that east and west have been transposed. With south at 60°, a magnetic orientation of N. 30° E. instead of N. 30° W. is obtained. Correcting for declination, the orientation on the bottom of the core is N. 47° E. Since the core is upside down, this value is reversed 180° giving a reading of S. 47° W. which checks by 7 degrees the S. 54° W. orientation obtained in (Fig. 1 A). This reversal of 180° for upside down condition is only

made possible if east and west are transposed on the bottom of the core as explained above.

This is the simplest method of correcting an upside down core, for it is made graphically, which obviates chances for error. Another method for transferring the location of true south from the bottom to the top of the core is to deduct the location of the south pole as found on the resultant curve from 360°.

South on Curve @	360° 60°
Location of South Pole Bedding on Diagram @	300° 270°
Magnetic Orientation Declination	S. 30° W. +17°
True Dip	S. 47° W.

All corrections must be based on the magnetic orientation and not on the true orientation after applying the declination correction of the locality. If, for an example, a core has been sent in for orientation with the bottom erroneously marked as top, the results will have no meaning. They can be recalculated, however, with little difficulty. For example:

Results obtained show a dip to the N. 56° E. (true) when bottom is run as top, which does not conform in any way to the suspected structural picture, the dip in that particular locality being thought to be more nearly southeasterly. Magnetic declination is 16° east of north.

Result from Orienter Curves (Magnetic) Magnetic Declination	N. 40° E. + 16°
True Orientation	N. 56° E.

Transposing east to west for upside down core, N. 40° W. (magnetic) is obtained.

	N. 40° W.
Magnetic Declination	−16°
	N. 24° W.

Reversing 180° for upside down core, the true orientation of this core is, therefore S. 24° E. and not N. 56° E.

This method of transposing east and west on reversed cores does

not help where the top and bottom of a core are unknown, but it does help if in a series of cores, results on one or two cores are entirely out of line with the others. These "out-of-line" results can be assumed to be due to reversed cores, and by transposing east and west the ensuing results will be about 180° off from the group in the series which check themselves.

Another simple method of correcting the magnetic orientation of an upside down core has been worked out and proved by the above described laboratory work. This is done by not reversing east and west 180°, but reversing north and south 180° only and leaving east and west as determined. The magnetic orientation only can be used in this type of correction.

Using the same example given above where an orientation was found to be N. 56° E. (true):

Therefore:	
Magnetic Orientation is	N. 40° E.
Reversing North to South, a	S. 40° E. dip is obtained
Magnetic Declination	−16
True Orientation	S. 24° E.

which checks correction by other methods. Similarly, a magnetic orientation on an upside down core of N. 30° W. can be changed to S. 30° W. Correcting for 17° declination, the final true orientation is S. 47° W.

Figs. 2 and 3 show a series of diagrammatic results on known cores. Fig. 2 shows the results on true tops and Fig. 3 shows the results on true bottoms run as tops. To these latter have been applied the Brunton Compass points, giving the results on the bottom approximately 180° from the true orientation. It will be evident that on these diagrams all points have the same spatial position even though, for example, the south pole on No. 1, Fig. 2 is at 307° and at 60° in Fig. 3 representing the bottom of the core.

It can be clearly seen from the above diagrams the importance of knowing the true top of a core. For example, in No. 4 Fig. 3 if east and west had not been transposed the orientation obtained would have been S. 25° E. (magnetic) or S. 08° E. after correcting for declination. This S. 08° E. orientation would have been nowhere near the true N. 42° E. dip obtained on the true top (No. 4, Fig. 2)

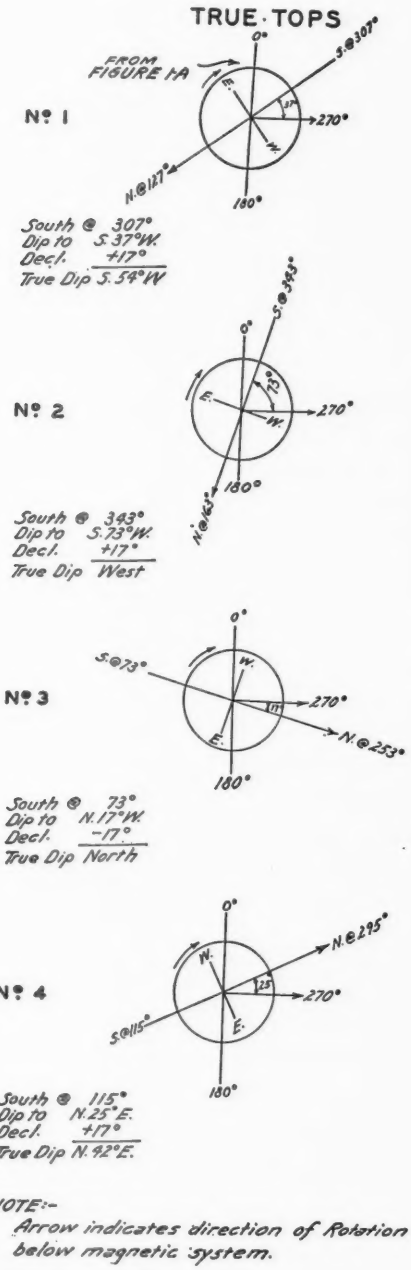


FIG. 2. Diagrammatic results on known cores with correctly marked tops.

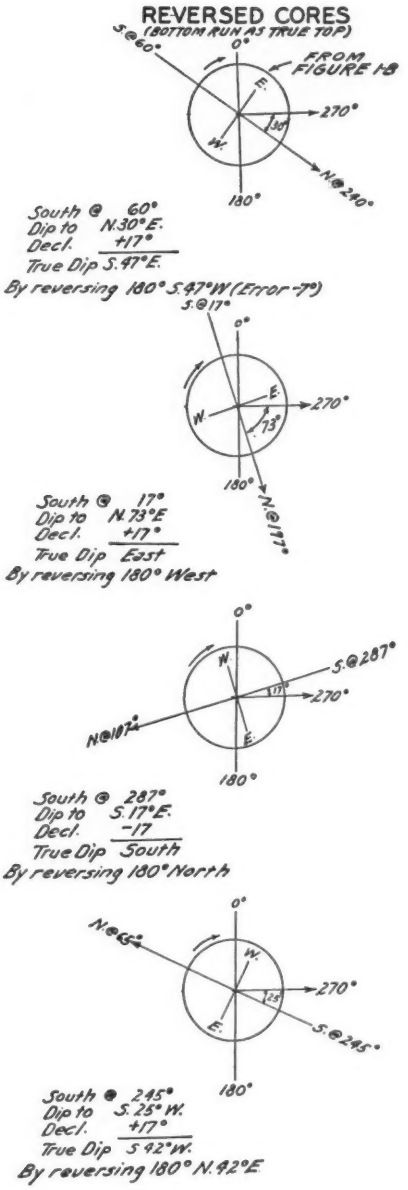


FIG. 3. Diagrammatic results on cores of Fig. 2 but with true bottoms run as tops.

SUMMARY

The purpose of this paper is to show how important it is to mark cores correctly as to their tops. Much time and money is wasted in incorrect markings. Many instances have been known where cores have been marked incorrectly on purpose because the sender of the core thought he might withhold the true structual conditions. Not being familiar with the correction described in this paper, his results were of no use to him. The best safeguard is to mark the core as it comes out of the barrel. If there is any doubt as to the correctness of the true top, then the upside down correction can be applied and nine times out of ten the corrected reversed orientation will fit the structural picture.

ACKNOWLEDGEMENTS

The author wishes to thank officials of the Standard Oil Company of California, particularly R. A. Halloran, Manager of the Research and Development Department, and also G. L. Kothny, Vice-President of the Sperry-Sun Well Surveying Company, for permission to publish this paper. The writer is also indebted to H. N. Herrick of the Standard Oil Company of California, Dwight C. Roberts and E. R. Webb of the Sperry-Sun Well Surveying Company for their criticism of the paper.

REFERENCES

For a more detailed explanation of the method, the following references are given:

[1] E. D. Lynton, Laboratory Orientation of Well Cores by their Magnetic Polarity, Bull. A. A. P. G., Vol. 21, No. 5, May, 1937.

[2] Further Recent Developments in Laboratory Orientation of Well Cores by their Magnetic Polarity. GEOPHYSICS, Vol. 3, No. 2, March, 1938.

[3] Dwight C. Roberts and E. Ray Webb, "Polar Core Orientation." Paper presented at Tech. Meeting, Oil World Exposition, Houston, Texas, April 24–29, 1939.

DISCUSSIONS AND COMMUNICATIONS

In order to clear up some misunderstanding which has arisen due to publication of erroneous reports, the following announcement has been requested.

RADIOACTIVE WELL LOGGING SERVICE

Lane-Wells Company, pioneers in the field of gun perforating, has been granted a license under the patents of Well Surveys, Inc., of Tulsa, Oklahoma, to practice radioactivity well surveying. This license is exclusive except for two non-exclusive licenses limited to operations on properties operated by the licensees and a license reserved by Well Surveys, Inc., to continue the practice of radioactivity well surveying. Well Surveys, Inc. will manufacture all detecting and recording instruments used by Lane-Wells.

This new method of well surveying permits the logging of formations through casing, thus overcoming the limitations of present electrical logging which can be performed only in uncased holes. Lane-Wells is now offering this new logging service in Oklahoma and Kansas and will extend the service to other oil fields as soon as practicable.

Contrary to erroneous reports published in certain Oklahoma papers, Lane-Wells Company has not taken over either the service or equipment of Well Surveys, Inc., Seismograph Service Corporation, and Engineering Laboratories. Inc. The confusion shown in published reports was probably occasioned by the fact that the owners of Seismograph Service Corporation and Engineering Laboratories, Inc. are also stockholders in Well Survey, Inc.

REVIEWS

ANNOUNCEMENT OF NEW BOOKS

Three new books on Geophysical Exploration methods are now available or in the process of printing. It is unfortunate that at the time of going to press, suitable reviews were not available for publication in your Journal. However, in view of their importance the following announcements concerning them should be of interest. Reviews of these books will appear in the next number of GEOPHYSICS.

EDITOR

Geophysical Prospecting for Oil, by L. L. Nettleton. 444 pages, 6×9, 177 illustrations. Price $5.00. Published by McGraw-Hill Book Co., Inc., 330 W. 42 Street, New York City.

This book offers a concise introduction to the four principal methods of geophysical prospecting covering the theory, apparatus, field work and emphasizing the practical interpolation of results in the light of the oil prospector's needs.

Exploration Geophysics, by J. J. Jakosky. 800 pages, 430 illustrations. Price $8.00. Published by Times-Mirror Press, 110 South Broadway, Los Angeles, California.

This volume describes the fundamental theories, equipment and field techniques of the recognized exploratory geophysical methods and illustrates their application to problems of economic geology.

Geophysical Exploration, by Carl A. Heiland. Approx. 1000 pages, 510 illustrations. Price $10.00. Published by Prentice-Hall, Inc., 70 Fifth Avenue, New York City.

This book encompasses a thorough discussion of geophysical procedures and apparatus, calculations and interpretations of methods and applications. The results obtained by geophysics under a variety of geological conditions are presented with pertinent illustrations selected from various parts of the world.

SCALES FOR EVALUATING COMPONENTS OF MAGNETIC ATTRACTION

A set of scales has been developed by the Geophysical Section of the Geological Survey, United States Department of the Interior, by means of which magnetic anomalies due to geologic bodies of any size or shape on any known or assumed distribution of magnetization may be evaluated.

While these scales were originally constructed for evaluating magnetic anomalies, they are equally useful for solving problems involving all fields under the inverse square law, such as gravitational attraction, electric fields, intensity of illumination, etc.

A set of 39 scales, drawn on a scale modulus of one inch equals one unit, on two sheets (Series 1, Parts 1 and 2) suitable for mounting, has been photolithographed from a master set prepared by the Section of Geophysics. The set contains one scale for each multiple of ½ unit from one to twenty units inclusive. The scale values are computed for a point source of pole strength of 1,000 magnetic units.

The charts are purchaseable from the Director, Geological Survey, Washington, D. C., for 25 cents each (50 cents a set).

PATENTS*

ELECTRICAL PROSPECTING

U.S. No. 2,207,060, John J. Jakosky, Iss. 7/9/40, Appl. 9/7/37.

Method and Apparatus for Electrical Exploration of the Subsurface—A multi-circuit arrangement of surface electrodes with suitable switching arrangement whereby rapidly to effect measurements of near-surface inhomogeneities concurrently with those at depth and thus permit isolation of effects due to structure at depth. Apparatus includes circuits whereby ratios between current and potentials are determined by a calibrated null-reading comparator circuit comprising an oscillator and rectifier which allow comparison between circuits while keeping the circuits isolated.

U.S. No. 2,211,125, John J. Jakosky, Iss. 8/13/40, Appl. 7/5/39.

Method and Apparatus for the Electrical Exploration of the Subsurface—Electrical prospecting with one movable current electrode and three fixed electrodes which are moved by steps to obtain overlapping logs of the area so that local irregularities at the moving electrode can be discounted. Apparatus includes an electronic ratio meter to compare energizing current and electrode potential.

GEOCHEMICAL PROSPECTING

U.S. No. 2,210,546, Gerald L. Hassler, Iss. 8/6/40, Appl. 2/14/38, Assign. Shell Development Company.

Soil Gas Sampling Device and Method—A shallow gas sampler with multiple seals against the earth's surface or bore-hole walls to establish an inner sample-taking suction zone and an outer zone of greater suction which prevents seepage of air into the sampled zone. An adaptation of the guard-ring principle in electrical arts.

U.S. No. 2,212,681, Thomas H. Dunn, Iss. 8/27/40, Appl. 7/26/38, Assign. Stanolind Oil and Gas Company.

Soil Gas Analysis—Methane and heavier gases in soil or soil gas sample are condensed at liquid-air temperature, and methane is then removed at less than 0.1 micron pressure so that remaining hydrocarbons may be determined. Pressure-temperature curve on heating residual may be used to determine composition. Remaining gas may be burned and CO_2 measured to determine amount of ethane and heavier hydrocarbons.

U.S. No. 2,213,904, Thomas H. Dunn, Iss. 9/3/40, Appl. 7/22/38, Assign. Stanolind Oil and Gas Company.

Geochemical Prospecting—Soil waxes are determined by comparing color of their solutions in an organic solvent with known standards of color. The comparator may comprise photo-electric equipment.

U.S. No. 2,213,905, Joseph B. Clark, Iss. 9/3/40, Appl. 12/4/39, Assign. Stanolind Oil and Gas Company.

Geochemical Prospecting—Hydrocarbons in soil samples are measured by absorbing them in organic solvents and measuring the change of refractive index.

* Quarterly listings provided by Gary Muffly, G. R. & D. Co.

MAGNETIC

U.S. No. 2,211,158, John M. Pearson, Iss. 8/13/40, Appl. 9/13/38, Assign. Sperry-Sun Well Surveying Company.

Method of Orienting Cores—A core is rotated near one pole of an astatic horizontal magnetometer. Magnetometer deflections for various positions of the core are used to determine the direction of magnetization of the core so that its original orientation may be determined. Core may be embedded in non-magnetic material during the test.

MISCELLANEOUS

U.S. No. 2,209,140, Istvan Rybar, Iss. 7/23/40, Appl. 7/6/38, Assign. ½ to Pracisions Mechanische und Optische Austalt F. Süss A. G.

Damping Mechanism for Oscillating Systems—A torsion balance beam or the like pendular motion is damped by a frictionally pivoted fork between whose tines the beam oscillates. Thus the fork absorbs energy of initial high amplitude oscillations quickly reducing them to a value where normal air damping can function. Fork motion is restricted by resilient stops so that fork cannot contact pendulum over a small range near its equilibrium position.

SEISMOGRAPH PROSPECTING

U.S. No. 2,203,140, W. G. Green, Iss. 6/4/40, Appl. 2/27/37.

Method for Seismic Prospecting—A shock-producing or shooting device to improve frequency characteristics and to improve downward directivity of the shock characterized by building up a high pressure in the device and releasing it suddenly against the earth. Shearing or rupturing element affects the release.

U.S. No, 2,207,398, Francis M. Floyd, Iss. 7/9/40, Appl. 2/7/38, Assign. F. M. Kannenstine, Houston, Texas.

Seismic Surveying—A time-controlled filter arrangement for seismic recording channels including filter devices and means for varying the frequency characteristics of the amplifiers so as to decrease the lower cut-off point as a function of time elapsed after arrival of the initial wave. Apparatus specifications show motor driven variable resistors in grid circuit of a resistance coupled amplifier but claims are not specific to this means.

U.S. No. 2,209,100, John P. Minton, Iss. 7/23/40, Appl. 2/19/38, Assign. Socony-Vacuum Oil Company.

Electric Seismograph—Seismic filter of M-derived type to attenuate highly certain low frequencies, to emphasize certain high frequencies, and provide phase correction.

U.S. No. 2,212,988, David K. Kirk, Iss. 8/27/40, Appl. 6/17/39, Assign. Gulf Research & Development Company.

Apparatus for Transmitting and Recording Shot Moments—Mechanism for transmitting additional timed impulses in addition to shot impulse to assist identification of shot moment through obscuring interference.

WELL LOGGING

U.S. No. 2,203,729, John J. Jakosky and Patrick B. Lyons, Iss. 6/11/40, Appl. 11/19/38, Assign. Schlumberger Well Surveying Corporation.

Method and Apparatus for Use in Determining the Geologic Nature and Characteristics

of a Formation Traversed by a Bore Hole—Well logging for anisotropy. Current is passed parallel and normal to strata to determine electrical impedance in both directions. Indicator is sensitive to differences or ratios between parallel and normal impedances.

U.S. No. 2,206,863, Raymond T. Cloud, Iss. 7/9/40, Appl. 4/5/39, Assign. Stanolind Oil and Gas Company.

Electrical Logging of Earth Formations—Well logger records the ratio of the natural potential differences between each of two well electrodes and a third electrode which may be midway between the well electrodes or at the earth's surface. Show rectifiers and automatic polarity changers to prevent a false record where strata have natural potentials reverse of normal.

U.S. No. 2,206,864, Raymond T. Cloud, Iss. 7/9/40, Appl. 4/11/39, Assign. Stanolind Oil and Gas Company.

Electrical Logging of Earth Formations—Stratigraphic interfaces in wells are located with improved definition by recording differences in vertical gradients of natural earth potentials picked up by a series of three or four vertically disposed well electrodes. Uses bridge circuit or differential voltmeter.

U.S. No. 2,206,890, Paul F. Hawley, Iss. 7/9/40, Appl. 5/27/38, Assign. Stanolind Oil and Gas Company.

Electrical Logging of Wells—Current electrodes on eath's surface—one near the bore and one farther away. Potentials are measured between a well electrode and another electrode in the well or at the surface near the well. Uses A.C. or D.C.

U.S. No. 2,206,891, Paul F. Hawley, Iss. 7/9/40, Appl. 6/17/38, Assign. Stanolind Oil and Gas Company.

Electrical Logging of Earth Formations—Three well electrodes used in a bridge circuit energized by D.C. or A.C., or synchronous commutation. Unbalance of the bridge due to changing formation resistivity is recorded. Five electrodes may be used in a double bridge arrangement to indicate both local detail and regional variations in the formations traversed.

U.S. No. 2,206,892, Paul F. Hawley, Iss. 7/9/40, Appl. 6/17/38, Assign. Stanolind Oil and Gas Company.

Electrical Logging of Earth Formations—Electrical well logging using one current electrode in the well and one on the surface at a distance from the well. Potential electrodes spaced one above and below the current electrode in the well are used to detect unbalance due to discontinuities in formations traversed.

U.S. No. 2,206,893, Paul F. Hawley, Iss. 7/9/40, Appl. 7/7/38, Assign. Stanolind Oil and Gas Company.

Method and Apparatus for Logging Wells—Two current electrodes at the surface on opposite sides of a well cause a current to flow transversely across the well bore the density of current at any depth being related to the conductivity of the strata at that depth. Current density at various depths is measured by two horizontally disposed electrodes which traverse the well bore. In order to effect alignment of these potential electrodes with direction of current flow across the bore, the pair may be rotated so that twice per revolution a maximum potential difference is observable.

U.S. No. 2,206,894, Daniel Silverman, Iss. 7/9/40, Appl. 10/31/39, Assign. Stanolind Oil and Gas Company.

Method and Apparatus for Electrical Logging—Well is logged by comparison of currents of two well electrodes connected to a common source of EMF and a common return electrode at the surface. Differential ammeter records the relative currents in the two branch circuits.

U.S. No. 2,207,280, L. F. Athy and H. R. Prescott, Iss. 7/9/40, Appl. 2/3/38, Assign. Continental Oil Company.

Method of Electrical Logging—Well logging with a predetermined low frequency and a recording device responsive to this frequency while rejecting other interfering e.m.f's. Current electrodes and one of the potential electrodes may be placed at the surface.

U.S. No. 2,207,281, L. F. Athy and H. R. Prescott, Iss. 7/9/40, Appl. 4/16/38, Assign. Continental Oil Company.

Seismic Method of Logging Bore Holes—Two well detectors receiving continuous sound waves are connected with outputs adding to obtain a record having amplitude variations corresponding to the formations traversed. Source and detectors move through the well in fixed relationship. Each detector channel has an amplitude limiter.

U.S. No. 2,210,205, Raymond D. Elliott, Iss. 8/6/40, Appl. 3/30/39, Assign. Lane-Wells Co.

Water Intrusion Location in Oil Wells—An oxidizing agent is distributed through a well and its dilution by water intrusion is detected by measurement of polarization of an electrode.

U.S. No. 2,210,795, Raymond T. Cloud, Iss. 8/6/40, Appl. 2/16/39, Assign. Stanolind Oil and Gas Company.

Method and Apparatus for Electrical Logging—Electrical well logger which plots rate-of-change (with respect to time) of resistivity or self e.m.f. as a function of depth to emphasize indication of boundaries between various strata. Recording galvanometer compares the detected voltage with a voltage generated in proportion to electrode velocity through the well.

U.S. No. 2,211,124, J. J. Jakosky, Iss. 8/13/40, Appl. 3/11/39.

Method for Continuously Exploring Boreholes—Dip measurement in which bore is logged using the drill and uninsulated drill stem as one current electrode. Return current electrodes are placed in different directions from the well and are used alternately. The values so obtained are compared to obtain information on the dip of strata traversed.

U.S. No. 2,206,922, Alonzo L. Smith, Iss. 7/9/40, Appl. 8/8/38, Assign. 20% to Starr Thayer.

Means and Method for Locating Oil Bearing Sands—Mud from drilling well passes under ultra-violet light and fluorescence detector. Fluorescence indicates presence of oil.

U.S. No. 2,213,138, John T. Hayward, Iss. 8/27/40, Appl. 7/1/39.

Method and Apparatus for Detecting Oil in Well Drilling—Oil in drill mud is detected by fluorescence induced in the oil by a fluorescence-exciting ray.

THE SOCIETY ROUND TABLE

ANNUAL MEETING, HOUSTON, TEXAS, APRIL 1, 2 AND 3, 1941

The Annual meeting of the Society will be held at the Rice Hotel in Houston, Texas on April 1, 2 and 3, 1941.

The following members have been asked to serve as a member of the program committee in their respective areas:

E. A. Eckhardt—Atlantic Coast Area
J. A. Sharpe—Tulsa Area
C. A. Heiland—Rocky Mountain Area
Henry C. Cortes—Dallas-Fort Worth Area
Herbert Hoover, Jr.—Pacific Coast Area
Frank Goldstone—Houston Area
T. I. Harkins—Houston Area
W. M. Rust, Jr.—Houston Area
H. B. Peacock (General Chairman)—Houston Area

Those desiring to present papers at this meeting are requested to notify any member of this committee.

The above committee members from the Houston Area will also serve as a general committee on arrangements for the convention.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the Secretary within thirty days. (Names of sponsors are placed beneath the name of each nominee.)

ACTIVE

Charles B. Aiken
E. G. Leonardon, R. Henquet, L. B. Slichter
Frank Tilbury Allen
E. A. Eckhardt, L. L. Nettleton, R. D. Wyckoff
Thomas Judson Bevan
J. C. Pollard, Henry C. Cortes, J. P. Minton
Richard Dale Buck
E. G. Leonardon, R. Henquet, J. J. Jakosky
Peter Paul Conrad
Adrian E. Mix, C. H. Gerdes, L. M. Mott-Smith
Vernon Tracy Donnelly
Robert H. Ray, Hart Brown, N. P. Teague
John A. Gilmore
Andrew Gilmour, John L. Ferguson, Jess Vernon
George Herbert Hazen
W. W. Hardy, H. R. Moorman, C. H. Dix
Glen Donald Lambert
H. M. Evjen, J. P. Woods, F. Goldstone

Paul H. Ledyard
R. Clare Coffin, Sidon Harris, Joseph A. Sharpe
John Marshall Nash
H. M. Evjen, J. P. Woods, F. Goldstone
Austin Barrett Penney
B. O. Winkler (Article III-C-1 of the Constitution)
Henry Clay Reichert
George B. Lamb, R. D. Wyckoff, W. J. Osterhoudt
Virgil Willard Teufel
J. W. Thomas, J. W. Hoover, K. H. Crandall
Jack Christopher Van Valkenburgh
Andrew Gilmour, L. Y. Faust, O. C. Lester, Jr.

ASSOCIATE

James Albert Ballard
J. E. Hawkins, Dart Wantland, W. S. Levings
William Robert Campbell
Ray K. Carter, Jack B. Cooper, Jake Moon
Joseph Hawes Church
S. Zimerman, P. S. Williams, George E. Wagoner
Forrest Frank Lambrecht
Dart Wantland, C. A. Heiland, A. A. Hunzicker
Joos Johannes Hermanus Jansen Manenschijn
(Article III-C-1 of the Constitution)
James Wesley Richardson
F. W. Borman, Andrew Gilmour, L. Y. Faust
Willard Russel Slater
J. E. Hawkins, Dart Wantland, C. A. Heiland
Daniel Hastings Woodard
R. D. Wyckoff, E. A. Eckhardt, J. C. Heggblom

PERSONAL ITEMS

(Members are requested to send material for publication herein to
J. F. Gallie, P. O. Box 777, Austin, Texas.)

CLAY K. MYERS has advised that his address is now c/o John G. Myers Company, Albany, New York.

LYNN ERVIN, newly-elected associate member connected with the Stanolind Oil and Gas Company, has been transferred to Edna, Texas, where he may be addressed at P. O. Box 565.

T. J. O'DONNELL has accepted a position in South America with the Mene Grande Oil Company, Apartado 45, Barcelona, Venezuela.

O. F. VAN BEVEREN should be addressed at 4361 Colfax Avenue, North Hollywood, California.

C. J. CHARSKE, JR., has returned from the Netherlands East Indies and is located at 4222 Avondale, Dallas, Texas.

MAURICE EWING is now an Associate in Submarine Geology with the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

DONUIL HILLIS, geologist with California Lands, Inc., is now located at 785 Market Street, San Francisco, California.

JOHN G. KOENIGSBERGER, a member of the Committee on Geophysical Methods of Exploration of the American Institute of Mining and Metallurgical Engineers, is temporarily in Steinau i. Odenwald, Germany.

GEORGE B. SOMERS' Dallas address is 4336 Bowser Street. He recently returned rom work in Egypt.

C. BARRINGTON BROWN may now be addressed at P. O. Box 1, Hertford, Herts, England.

GARDNER P. WILSON has accepted a position with the Lockheed Aircraft Corporation in Burbank, California. He is residing in Pasadena at 150 South Madison.

S. J. ASTBURY, Secretary of the Institute of Petroleum, advises that headquarters have been transferred to the University, Edgbaston, Birmingham 15, England. The Institute's Library at the Adelphi in London is not available for consultation, due to war-time conditions.

DWIGHT E. WARD, of the Carter Oil Company, has been transferred to Phillipsburg, Kansas, where he may be addressed at P. O. Box C.

CHARLES L. M. BLOCHER has accepted employment with the Sonotone Houston Company as manager of the Beaumont office. He is also acting as consultant. His Beaumont address is 1340 College Street.

The Independent Petroleum Association of America will convene in Dallas, Texas, October 16, 17, and 18, for its Eleventh Annual Meeting. A number of entertain-

ment features have been arranged by the local committee for those times during which no convention sessions are in progress. The National Stripper Well Association will convene October 15, the day preceding the IPAA meeting.

J. J. JAKOSKY has been appointed Dean of the School of Engineering and Architecture of the University of Kansas, in Lawrence, Kansas. His address in Lawrence is 1120 West Eleventh Street. Dr. Jakosky's new book, *Exploration Geophysics*, is now off the press.

CHARLES GILL MORGAN, of the United Geophysical Company, is temporarily located in Dallas, Texas. He may be addressed at 4608 Abbott Avenue.

A. VAN WEELDEN should be addressed c/o Shell Oil Company, Inc., Shell Building, Houston, Texas.

F. F. CAMPBELL has moved from Victoria to 3610 Cason, Houston, Texas.

NATHAN C. DAVIES has moved from Centralia to Fairfield, Illinois, where he may be addressed at P. O. Box 146.

J. B. MEITZEN, of the Humble Oil and Refining Company, is now located in Mobile, Alabama, where he may be addressed at P. O. Box 1273.

VINCENT EMANUEL may be reached c/o AGIP, Via Roma 4, Casalpusterlengo (Milano), Italy.

A. B. WINTER, Electrolog supervisor with the Lane-Wells Company, is now located at 2 NW Tenth Street, Oklahoma City, Oklahoma.

SAM ZIMERMAN, of the Carter Oil Company, may be addressed at P. O. Box 387, Philip, South Dakota.

ROLAND F. BEERS, President of the Geotechnical Corporation, announces that a research laboratory has been opened at 580 Massachusetts Avenue, Cambridge, Massachusetts, for the investigation of geophysical problems. Mr. Beers is taking personal charge of the research program and is located in Cambridge.

WALTER D. BAIRD, of Geophysical Service, Inc., has been transferred to Martinez, California, and may be addressed at P. O. Box 31.

EDWARD S. FOSTER, JR., of the Halliburton Oil Well Cementing Company, is now located in Houma, Louisiana.

W. HAFNER may now be addressed c/o Shell Oil Company, Inc., Shell Building, Houston, Texas.

L. F. FISCHER is now associated with the Gulf Oil Company as a geophysical scout. He is at present located in Meridian, Mississippi, where he may be reached at P. O. Box 1451.

O. A. SEAGER, of the Carter Oil Company, may be addressed at P. O. Box 358, Bismarck, North Dakota.

J. C. HEGGBLOM has been transferred to Fresno, California, where his mailing address is P. O. Box 1089.

IRA H. CRAM has been appointed Assistant to the Chief Geologist of the Pure Oil Company, and now has his offices in Chicago, Illinois, at 35 East Wacker Drive. His residence address is 560 Sheridan Road, Winnetka, Illinois.

The Geological Society of America will convene in Austin, Texas, December 26–28, at the University of Texas. The Society of Exploration Geophysicists has printed a number of the historical articles which appeared in the July issue of GEOPHYSICS in a special folder for distribution at that meeting. They are not otherwise available.

B. DE BLANK has been transferred to B. P. M., Balik Papan, Netherlands East Indies.

F. H. AGEE is now located at the Gilmer Hotel in Columbus, Mississippi.

W. W. WARING is now connected with the International Petroleum Company, Casilla 803, Guayaquil, Ecuador, South America.

P. M. HONNELL, formerly at the California Institute of Technology, has been appointed Assistant Professor of Electrical Engineering at Southern Methodist University in Dallas, Texas.

HARRIS COX has advised the Society that he should now be addressed at 1311 Republic Bank Building, Dallas, Texas.

W. H. GAYMAN is now connected with the Lockheed Aircraft Corporation in Burbank, California, where his residence address is 235 North Grinnell Drive.

GEORGE C. HOWARD may be addressed at P. O. Box 1739, Shreveport, Louisiana.

HARRY R. IMLE, of the Carter Oil Company, is now located in Ardmore, Oklahoma. His mailing address is P. O. Box 197.

CLARE N. HURRY, Party Chief for the Carter Oil Company, should be addressed at P. O. Box 801, Tulsa, Oklahoma.

LYMAN CHANDLER, JR., has returned from South America, and may be addressed c/o National Geophysical Company in Columbus, Mississippi.

H. J. MCCREADY has been appointed Party Chief of a Mott-Smith gravimeter party, and may be addressed c/o T. F. Roche, Apartado Aero 32, Barranquilla, Colombia.

J. D. BERWICK is in charge of a gravity meter party working for Northwest Company Limited, P. O. Box 433, Estevan, Saskatchewan, Canada. After October 31 he should be addressed at 56 Church Street, Toronto 2, Ontario, Canada.

BARTHOLD W. SORGE has advised the Society that he is now located at 1065 Kendall Drive, San Gabriel, California.

JOHN V. LONG is now located at 4120 Fifth Avenue, San Diego, California.

J. W. THOMAS, JR., of the Stanolind Oil and Gas Company, has been transferred from Liberal, Kansas, to Canadian, Texas.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS
CONSTITUTION AND BY-LAWS
(As amended to August 7, 1940)

I. NAME

This Association shall be called the "Society of Exploration Geophysicists."

II. OBJECT

The object of this Association is to promote the science of geophysics especially as it applies to exploration.

III. MEMBERSHIP

A—Members

1. Any geophysicist of recognized standing shall be eligible to membership, whether or not he is engaged in petroleum geophysics or in geophysical prospecting.
2. Any physicist, mathematician, geologist, or engineer of recognized standing who is investigating a geophysical problem or problems shall be eligible to membership.
3. Any geologist of recognized standing who is not a geophysicist of recognized standing, but who is acting as chief, or division chief in charge of geophysical surveying, shall be eligible to membership.

B—Associates

1. Any geophysicist, geologist, engineer, mathematician, or physicist who is a graduate of an institution of recognized scientific standing who is engaged in geophysics and who is not eligible to membership shall be eligible to associate membership.
2. Any person who is not a graduate of an institution of recognized scientific standing and who is not eligible to membership and who has shown ability in a routine phase of geophysical work and who is in a position of responsibility in geophysical surveying shall be eligible to associate membership.
3. Any representative or employee of a firm or corporation engaged in supplying equipment or supplies to the geophysical prospecting industry, provided such individual is the graduate of an institution of recognized scientific standing, or provided otherwise that such individual is qualified by adequate technical experience, shall be eligible to associate membership.
4. Associate members shall be known as associates.
5. Associates shall enjoy all the privileges of membership in the Society, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Society in professional cards or professional reports or otherwise.
6. The Executive Committee may advance to active membership, without the formality of application for such change, those associates who have, subsequent to election, fulfilled the requirements for active membership.

C—Student Members

1. Any graduate or undergraduate student in residence at a recognized university or college shall be eligible for student membership.

2. Student membership shall terminate one year after a student member ceases to be enrolled at a recognized university or college.
3. The privileges of student members shall be the same as those of associate members.

D—Election to Membership

1. Every candidate for admission as a member or associate shall submit a formal application on an application form authorized by the Executive Committee, signed by him, and endorsed by not less than three members who are in good standing, stating his training and experience and such other facts as the Executive Committee shall from time to time prescribe. Provided the Executive Committee, after due consideration, shall judge that the applicant's qualifications meet the requirements of the Constitution, they shall cause to be published in an appropriate publication the applicant's name and the names of his sponsors. If, after at least thirty days have elapsed since such publication, no reason is presented why the applicant should not be admitted, he shall be deemed eligible to membership or to associate membership, as the case may be, and shall be notified of his election. Provided the Executive Committee may accept applicants for either class of membership, who, because of their geographical location or because of their lack of acquaintance with active members of this Society, are unable to secure qualified sponsors, but who otherwise are eligible for membership. Applicants for student membership may be accepted as student members upon recommendation of a faculty member of the school they are attending, and with the unanimous approval of the Executive Committee.
2. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the regular Society publications for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice has been mailed of his election, the Executive Committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the current year and until such written notice and card are received, he shall in no way be considered a member of the Society.

E—Honorary Members

1. The Executive Committee may from time to time and by unanimous action elect as honorary members persons who have contributed distinguished service to the cause of geophysics. Honorary members shall not be required to pay dues.

F—Code of Ethics

1. Membership of any class shall be contingent upon conformance with the established principles of professional ethics.

IV

A—Resignation—Suspension—Expulsion

1. Any member or associate may resign from the Society at any time. Such resignation shall be in writing and shall be accepted by the Executive Committee, subject to the payment of all outstanding dues and obligations of the resigning member or associate.

2. Any member or associate who is more than one year delinquent (in arrears) in payment of dues shall be suspended from the Society. Any delinquent or suspended member or associate, at his own option, may request in writing that he be dropped from the Society and such request shall be granted by the Executive Committee. Any member or associate more than two years in arrears shall be dropped from the Society. The time of payment of delinquent dues for either one year or two years may be extended by unanimous vote of the Executive Committee.
3. Any member or associate who resigns or who is dropped under the provisions of Sections 1 and 2 of this article ceases to have any rights in the Society and ceases to incur further indebtedness to the Society.
4. Any person who has ceased to be a member or associate under Section 1 or Section 2 of this article may be re-instated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member or associate of the Society.
5. Any member or associate who, after being granted a hearing by the Executive Committee, shall be found guilty of a violation of the code of ethics of this Society or shall be found guilty of a violation of the established principles of professional ethics or shall be found guilty of having made a false or misleading statement in his application for membership in the Society, shall be asked to resign from the Society by unanimous vote of the Executive Committee. The decision of the Executive Committee in all matters pertaining to the interpretation and execution of the provisions of this section shall be final.

V. Officers and Their Duties

A—Officers

1. The officers of the Society shall be a President, a Vice-President, a Secretary-Treasurer, and an Editor. These, together with the Past President, shall constitute the Executive Committee and managers of the Society. Officers shall be elected for a term of one year with the exception of the Editor, who shall be elected for a term of three years.
2. A ticket of nominations for officers and representatives shall be prepared by a Committee on Nominations which shall consist of the President and the two qualified Past Presidents in order of precedence. Favorable action of this Committee shall be two out of three votes. This Committee shall nominate two candidates for President, one of whom shall be the retiring Vice-President, and two candidates for each of the other offices to be filled.

   The ticket prepared by the Nominating Committee, as well as any other ticket presented in writing and signed by at least twenty members in good standing, shall be submitted to the President by November 30. The President shall secure written acceptance of nominations from each candidate. The names of nominees shall be placed on the official ballot which shall be mailed to each member not later than December 15. Names of candidates shall be listed alphabetically except that the name of the retiring Vice-President shall occupy first place on the ticket. Blank spaces shall be provided on the ballot for writing in nominations for each office.

   Each member shall cast one vote for each officer to be elected and shall return

his ballot to the Secretary-Treasurer. Ballots to be valid must be enclosed in an envelope carrying on the outside the written signature of the member submitting the ballot, and must be received by the Secretary-Treasurer at his officially recognized address not later than ten days prior to the Annual Meeting. Only ballots received from members in good standing as of a date ten days prior to the Annual Meeting shall be valid. The Secretary-Treasurer shall indicate which ballots are valid by initialing the enclosing envelope and shall deliver the ballots unopened to the Nominating Committee for counting.

The Nominating Committee shall count the ballots immediately before the Annual Business Meeting. The candidate receiving the greatest number of valid votes cast for an office shall be declared elected to that office. In case of a tie, the Nominating Committee shall decide by a secret vote which of the candidates tied shall be elected.

The announcement of the election shall be made as the first of the new business considered at the Annual Meeting.

3. No one shall hold the office of President for two consecutive years and no one shall hold any other office for more than two consecutive years except that of Editor.

B—Duties of Officers

1. The President shall be the presiding officer at all the meetings of the Society, shall take cognizance of the acts of the Society and of its officers, shall appoint such committees as are required for the purposes of the Society, and shall delegate members to represent the Society. He may, at his option, serve on, and may be chairman of, any committee.
2. The Vice-President shall assume the office of President in case of a vacancy from any cause in that office and shall assume the duties of President in case of the absence or disability of the latter. He shall also act as Chairman of the Program and Arrangements Committee of the Society.
3. The Secretary-Treasurer shall assume the duties of the President in case of the absence of both the President and Vice-President. He shall have charge of the financial affairs of the Society and shall annually submit reports as Secretary-Treasurer covering the fiscal year, which he shall arrange to have published in the next regular issue of the recognized organ of the Society. He shall receive all funds of the Society and, under the direction of the Executive Committee, shall disburse all funds of the Society. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded, all employees to whom authority may be delegated to handle Society funds. The amount of such bonds shall be set by the Executive Committee and the expense shall be borne by the Society. The funds of the Society shall be disbursed by check as authorized by the Executive Committee.
4. The Editor shall be in charge of the editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the regular Society publication and for special publications, and may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

5. In the event of absence, disability or resignation of any member of the Executive Committee, the vacant place in the Committee shall be automatically filled by the next preceding qualified Past President who shall be known as Prior Past President.
6. The officers shall assume the duties of their respective offices immediately after the Annual Meeting following their election.

VI. Executive Committee—Meetings and Duties

A—Executive Committee

1. The Executive Committee shall consist of the President, Past President, Vice-President, Secretary-Treasurer, and Editor.

B—Meetings and Duties

1. The Executive Committee shall meet preceding the annual meeting and at the call of the President may hold meetings when and where thought advisable, to conduct the affairs of the Society. A joint meeting of the outgoing and incoming Executive Committees shall be held immediately after the close of the annual Society business meeting. Members of the Executive Committee may vote by proxy, mail or person on all matters which call for favorable or unanimous action.
2. The Executive Committee shall consider all nominations for membership and pass on the qualifications of the applicants, shall have control and management of the affairs and funds of the Society, shall determine the manner of publication, and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Society, and to employ such persons as are needed to conduct the business of the Society. They are empowered to make investments of both general and special funds of the Society. Trust funds may be created giving to the trustees appointed for such purpose such discretion as to investments as seems desirable to the Executive Committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice. Favorable action shall consist of a favoring three out of five votes. Committee members may vote by person, proxy or in writing.

VII

A—Meetings

1. The Society shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held at a time and place designated by the Executive Committee. At this meeting the proceedings of the preceding meeting shall be read, Society business shall be transacted, scientific papers shall be read and discussed, and results announced of the mail ballot for officers for the ensuing year.

VIII

A—Amendments

1. Amendments to this Constitution may be proposed by a resolution of the Executive Committee, by a Constitutional Committee appointed by the President, or in writing by any ten members of the Society. All such resolutions or proposals

must be submitted at the annual meeting of the Business Committee of the Society as provided in the By-Laws, and only the Business Committee shall make recommendations concerning proposed constitutional changes at the annual Society business meeting. If such recommendations by the Business Committee shall be favorably acted on at the annual Society business meeting, the Secretary-Treasurer shall arrange for a ballot of the membership by mail within thirty (30) days after said annual Society business meeting, and a majority vote of the ballots received within ninety (90) days of their mailing shall be sufficient to amend. The legality of all amendments must be determined by the Executive Committee prior to balloting.

B—Parliamentary Regulations

1. The rules contained in "Robert's Rules of Order, Revised" shall govern the Society in all cases to which they are applicable, and in which they are not inconsistent with the By-Laws or the special rules of order of this Society.

BY-LAWS

I

A—Dues

1. The fiscal year of the Society shall correspond with the calendar year.
2. The annual dues of members of the Society shall be five dollars ($5.00). The annual dues of associates for not to exceed six years after election shall be four dollars ($4.00); thereafter, the annual dues of such associates shall be five dollars ($5.00). The annual dues of student members shall be three dollars ($3.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member, associate, and student member before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members, associates, or student members who shall fail to pay their annual dues by March fifteenth shall not receive further copies of the regular Society publication, shall not be eligible to vote, nor shall they be privileged to buy Society special publications at prices made to the membership, until such arrears are met.

II

A—Publications

1. The proceedings of the annual meeting, the Constitution and By-Laws, and the papers presented at such meeting shall be published at the discretion of the Executive Committee in the regular publication or in such other form as the Executive Committee may decide best meets the needs of the membership of the Society.
2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge the regular publication of the Society for that year. $3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, GEOPHYSICS.
3. The Executive Committee may authorize the printing of special publications to be financed by the Society from its general, publication or special funds and offered for sale to members and associates in good standing at not less than the cost of publication and distribution,

III

A—Regional Sections, Technical Divisions, and Affiliated Societies

1. Regional sections of the Society may be established provided the members of such sections are members of the Society and shall perfect an organization and make application to the Executive Committee. The Executive Committee shall submit the application for action first by the Business Committee and second to the Society for a letter ballot as for a constitutional amendment, and provided that the Society may revoke the charter of any regional section by similar action.
2. The Executive Committee may arrange for the affiliation with the Society of duly organized groups or societies, which by object, aims, constitution, by-laws, or practice are developing the study of geophysics or petroleum technology. In like manner, the Executive Committee may arrange conditions for dissolution of such affiliations. Affiliation with the Society need not prevent affiliation with other scientific societies. Members of affiliated societies who are not members of the Society, shall not have the privilege of advertising their affiliation with the Society on professional cards or otherwise, but shall be entitled to receive the regular publication of the Society upon payment of a fee equivalent to that charged an associate member.

IV

A—District Representatives

1. The Executive Committee may cause to be elected district representatives from districts which it shall define by a local geographic grouping of the membership. Such districts shall be redesignated and redefined by the Executive Committee as often as seems advisable. Each district shall be entitled to one representative for each seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the Executive Committee. They shall hold office for two years, their term of office expiring at the close of the annual meeting. In so far as possible, these two-year terms shall be overlapping.

V

A—Business Committee

1. The Executive Committee may institute a Business Committee to act as a council and advisory board to the Executive Committee and the Society. This Committee shall consist of the Executive Committee, the Prior Past President, and the district representatives. Favorable action by the Business Committee shall consist of a favorable two-thirds vote. The Secretary-Treasurer shall act as Secretary of the business meeting. Members of this Committee may vote in person, by proxy, or in writing. The Business Committee shall meet the day before the annual meeting at which time proposed changes in the Constitution or By-Laws may be considered, all old and new business shall be discussed, and recommendations may be voted for presentation at the annual meeting.

VI

A—Amendments

1. These by-laws may be amended by favorable vote of the Business Committee,

providing that such changes have been recommended and legality approved by the Executive Committee. Such amendments shall be published in the next regular number of the recognized organ of the Society.

AMENDMENTS TO THE CONSTITUTION AND BY-LAWS

In the recent balloting on the Constitution all the Amendments were adopted by large majorities.

QUESTION 1.—SHALL ARTICLE III BE AMENDED BY ADDING THE FOLLOWING PARAGRAPH:

Student Members:

1. Any graduate or undergraduate student in residence at a recognized University or College shall be eligible for Student Membership.

2. Student membership shall terminate one year after a student member ceases to be enrolled at a recognized University or College.

3. The privileges of student members shall be the same as those of Associate Members.

(NOTE: If the above amendment is adopted, the Executive and Business Committees agree to amend Article I of the By-Laws to provide yearly dues of $3.00 for this class of membership.)

Voted Yes 272; No 19

QUESTION 2.—SHALL PARAGRAPH C OF ARTICLE III BE AMENDED BY ADDING THE FOLLOWING SECTION:

Applicants for student membership may be accepted as student members upon recommendation of a faculty member of the school they are attending and with the unanimous approval of the Executive Committee.

Voted Yes 268; No 21

QUESTION 3.—SHALL ARTICLE V, PARAGRAPH A, SECTION 1 BE AMENDED BY ADDING THE FOLLOWING SENTENCE:

Officers shall be elected for a term of one year with the exception of the Editor who shall be elected for a term of three years.

Voted Yes 269; No 15

QUESTION 4.—SHALL SECTION 2 OF PARAGRAPH A, ARTICLE V BE AMENDED TO READ AS FOLLOWS:

A ticket of nominations for officers and representatives shall be prepared by a Committee on Nominations which shall consist of the President and the two qualified Past Presidents in order of precedence. Favorable action of this committee shall be two out of three votes. This committee shall nominate two candidates for President, one of whom shall be the retiring Vice-President, and two candidates for each of the other offices to be filled.

The ticket prepared by the Nominating Committee, as well as any other ticket presented in writing and signed by at least twenty members in good standing, shall be submitted to the President by November 30. The President shall secure written acceptance of nominations from each candidate. The names of nominees shall be placed on the official ballot which shall be mailed to each member not later than December 15. Names

of candidates shall be listed alphabetically except that the name of the retiring Vice-President shall occupy first place on the ticket. Blank spaces shall be provided on the ballot for writing in nominations for each office.

Each member shall cast one vote for each officer to be elected and shall return his ballot to the Secretary-Treasurer. Ballots to be valid must be enclosed in an envelope carrying on the outside the written signature of the member submitting the ballot, and must be received by the Secretary-Treasurer at his officially recognized address not later than ten days prior to the Annual meeting. Only ballots received from members in good standing as of a date ten days prior to the Annual meeting shall be valid.

The Secretary-Treasurer shall indicate which ballots are valid by initialing the enclosing envelope and shall deliver the ballots unopened to the Nominating Committee for counting.

The Nominating Committee shall count the ballots immediately before the Annual Business meeting. The candidate receiving the greatest number of valid votes cast for an office shall be declared elected to that office. In case of a tie, the Nominating Committee shall decide by a secret vote which of the candidates tied shall be elected.

The announcement of the election shall be made as the first of the new business considered at the Annual meeting.

Voted Yes 253; No 29

QUESTION 5.—SHALL SECTION 3, PARAGRAPH A OF ARTICLE V BE AMENDED TO READ:

No one shall hold the office of President for two consecutive years and no one shall hold any other office for more than two consecutive years except that of Editor.

Voted Yes 255; No 33

Of 545 active members eligible to vote as of August 7, 1940, 291 participated in the election. Five ballots had to be discarded because the voter failed to put his name on the outside of the envelope. One was discarded because the name was illegible. Six had to be discarded because the voters had not paid their dues.

SOCIETY OF EXPLORATION GEOPHYSICISTS
MEMBERSHIP LIST
(OCTOBER 1, 1939)

*Acheson, C. H., c/o Tropical Oil Co., Ltd., El Centro, Colombia, S. A.
Acker, Ralph F., 1162 E. 69th St., Los Angeles, Calif.
Adams, Hal R., 1702 Tower Petroleum Bldg., Dallas, Tex.
Adler, Joseph L., 2011 Esperson Bldg., Houston, Tex.
Affleck, James, P. O. Drawer 2038, Pittsburgh, Pa.
*Agee, F. H., Gilmer Hotel, Columbus, Miss.
Agocs, William B., Box 2038, Pittsburgh, Pa.
Alber, John L., Geop. Dept., International Petroleum Co., Negritos via Talara, Peru, S. A.
Albright, E. G., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Alexander, Warren A., c/o Romano-Americana, Ploesti, Roumania
Allen, Thomas. L., P. O. Drawer 2061, San Antonio, Tex.
Allon, Michael, P. O. Drawer 2038, Pittsburgh, Pa.
Alvarez, Manuel, Jr., Pedro Baranda #11, Mexico City, D. F.
Amaral, Irnack Carvalho do, Rua da Passagem, 48-Casa I, Rio de Janeiro, Brazil, S. A.
Anderson, John F., c/o Sun Oil Co., Beaumont, Tex.
Anderson, O. W., c/o Stanolind Oil and Gas Co., Box 591, Tulsa, Okla.
Antes, Leland L., 1801 Dismuke, Houston, Tex.
Arick, Millard B., Aptdo. 1026, Cuidad Trujillo, R. D.
Arthur, Marion A., 256 Humble Bldg., Houston, Tex.
Athy, L. F., Geop. Dept., Continental Oil Co., Ponca City, Okla.
Augenthaler, R. L., c/o California Co., 1500 Petroleum Bldg., Houston, Tex.
Augustat, George, 1311 Republic Bank Bldg., Dallas, Tex.

*Back, Denys H., 709 Park Lane Apts., Houston, Tex.
*Backman, John E., P. O. Drawer 2038, Pittsburgh, Pa.
Bader, Glenn E., Humble Oil and Refg. Co., 857 Humble Bldg., Houston, Tex.
*Bailey, George F., 2011 Esperson Bldg., Houston, Tex.
Bailey, Lothrop H., P. O. Drawer 2038, Pittsburgh, Pa.
Baird, Walter D., P. O. Box 31, Martinez, Calif.
Baker, Malcolm C., 256 Humble Bldg., Houston, Tex.
Banta, H. E., 2011 Esperson Bldg., Houston, Tex.
Barger, Thomas C., Linton, N. D.
*Barksdale, G. L., Aptdo. 100, Cucuta, Colombia, S. A.
Barling, Robert, 909 Shell Bldg., Houston, Tex.
Barnett, G. W. T., c/o Anglo-Iranian Oil Co., Geop. Dept., Masjid-i-Suleiman, Khuzistan, S. Iran
Barnette, L. Atmar M., 1331 Tulane St., Houston, Tex.
Barret, William M., Giddens-Lane Bldg., Shreveport, La.
Barthelmes, Albert J., Seismograph Service Corp., 709 Kennedy Bldg., Tulsa, Okla.
*Bastian, Joseph W., 2021 Vance Ave., Alexandria, La.
Batchelder, Dean E., 3918 W. 59th Place, Los Angeles, Calif.
*Batson, James Burton, 721 Browder St., Dallas, Tex.
*Bazhaw, W. O., Petty Geophysical Engineering Co., Box 2061, San Antonio, Tex.
Bazzoni, Charles B., Sun Oil Co., 1608 Walnut St., Philadelphia, Pa.
Beck, August F., Box 1251, Bartlesville, Okla.
Becker, H. C., c/o Seismograph Service Corp., 709 Kennedy Bldg., Tulsa, Okla.
Beers, Roland F., Geotechnical Corp., Research Laboratory, 580 Massachusetts Ave., Cambridge, Mass.
Beeth, Donald, Geop. Dept., Continental Oil Co., Ponca City, Okla.
Bench, B. M., c/o V. G. Bench, 6935 Crandon Ave., Chicago, Ill.
Benioff, Hugo, 220 N. San Rafael Ave., Pasadena, Calif.

* Indicates Associate Members.
† Indicates Honorary Members.

Benke, M. L., 929 S. Broadway, Los Angeles, Calif.
Bennett, Roy F., 2011 Esperson Bldg., Houston, Tex.
Bentz, Alfred, Invalidenstrasse 44, Berlin N4, Germany
*Beresford, Robert, 66 Sharia Ibrahim Pasha, Cairo, Egypt
*Berger, Joe C., 1311 Republic Bank Bldg., Dallas, Tex.
Bertram, A. C., 6403 Edloe, Houston, Tex.
*Berwick, J. D., 56 Church St., Toronto, Ontario, Canada
Bevier, George M., 911 Milam Bldg., San Antonio, Tex.
Bible, John L., 1435 E. 36th St., Tulsa, Okla.
Bilinsky, Solomon, 1428 Wentworth, Houston, Tex.
Bills, Robert N., Box 2040, Tulsa, Okla.
Bishop, F. L., 1613 National Bank of Tulsa Bldg., Tulsa, Okla.
Black, J. P., Republic Prod. Co., 1810 Petroleum Bldg., Houston, Tex.
Blanchard, William G., Box 593, Coral Gables, Fla.
Blau, L. W., Room 929, Humble Bldg., Houston, Tex.
Blevins, David C., III, Paleisweg 33, Medan, Sumatra, N. E. I.
*Blight, Richard E., Box 2040, Tulsa, Okla.
Bliss, Robert, Jr., Route 1, Box 9, Greeley, Colo.
Blocher, Charles L. M., 1340 College St., Beaumont, Tex.
Boccalery, Michael A., c/o Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
Bodor, Leslie, 270 Ferry Ave., East, Detroit, Mich.
Bolinger, John W., 256 Humble Bldg., Houston, Tex.
Bonillas, Ygnacio, Aptdo. 2760, Bogota, Colombia, S. A.
Boos, C. Maynard, 2036 Columbine, Denver, Colo.
Booth, W. N., address unknown
Boots, Paul H., Box 2038, Pittsburgh, Pa.
Borman, F. W., Box 2040, Tulsa, Okla.
Born, Milton C., Box 2040, Tulsa, Okla.
Born, W. T., Box 2040, Tulsa, Okla.
Boucher, F. G., 159 Humble Bldg., Houston, Tex.
Bowsky, Merle C., 1841 Richmond, Houston, Tex.
Bradbury, F. D., 8108 W. 4th, Los Angeles, Calif.
Bradford, Donald C., c/o Dept. of Physics, U. of Pittsburgh, Pittsburgh, Pa.
Bradley, R. M., 704 Masonic Bldg., Bartlesville, Okla.
Brenner, Morris, 2011 Esperson Bldg., Houston, Tex.
*Brewer, Ralph R., Jr., P. O. Box 513, St. John, Kan.
Brinckmeier, Georg, Hannover, Boedekerstr. 36, Germany
Brooks, J. A., Jr., 256 Humble Bldg., Houston, Tex.
Brooks, O. D., Humble Oil and Refg. Co., 256 Humble Bldg., Houston, Tex.
Brotherhood, G. Roy, Caracas Petroleum S. A., Aptdo. 89, Caracas, Venezuela, S. A.
Broussard, D. F., 2011 Esperson Bldg., Houston, Tex.
Brown, C. Barrington, P.O. Box 1, Hertford, Herts, England
Brown, C. Bradner, P. O. Box 889, McAllen, Tex.
Brown, Donald R., P. O. Box 272, Karachi, India
*Brown, H. Hallock, 1702 Tower Petroleum Bldg., Dallas, Tex.
Brown, Hart, P. O. Box 6005, Houston, Tex.
Brown, Leon D., Jr., 2629 Wichita, Austin, Tex.
Brown, Paul B., 909 Shell Bldg., Houston, Tex.
*Browning, K. A., 3120 Grand Ave., Dallas, Tex.
Browning, Paul, Geol. Dept., Standard Oil Co. of Venezuela, Caripito, Venezuela, S. A.
Bryan, A. B., Box 801, Tulsa, Okla.
Bryan, Carl L., P. O. Drawer 2038, Pittsburgh, Pa.
*Budd, Montgomery R., 304 Brandywine Blvd., Wilmington, Del.
Buffum, C. Emery, Box 42, Stratford, Tex.
*Bullock, Robert Lee, Box 801, Tulsa, Okla.
Burdine, N. T., 3808 Cedar Springs Road, Dallas, Tex.
Burg, Kenneth E., 1311 Republic Bank Bldg., Dallas, Tex.
*Burnett, Arthur C., Langham Insurance Co., 15th Floor Cotton Exchange Bldg., Houston, Tex.

*Burney, James H., 252 Humble Bldg., Houston, Tex.
Burrows, L. A., E. I. du Pont de Nemours & Co., Gibbstown, N. J.
*Burton, R. H., Box 2040, Tulsa, Okla.
Busch, H. W., 611 Esperson Bldg., Houston, Tex.
Butler, Mark D., Gulf Research and Development Co., Box 2038, Pittsburgh, Pa.
*Butler, W. W., 2212 Esperson Bldg., Houston, Tex.
Byers, J. W., 611 Esperson Bldg., Houston, Tex.

*Cady, Francis H., c/o Carter Oil Co., P. O. Box 1770, Meridian, Miss.
Caldwell, C. L., Drawer 2038, Pittsburgh, Pa.
Campbell, F. F., 3610 Cason, Houston, Tex.
*Carlson, Joe E., 2011 Esperson Bldg., Houston, Tex.
Carlton, Dave P., Box 2180, Room 868, Houston, Tex.
Carr, G. W., 2513 Gulf Bldg., Houston, Tex.
Carson, J. P., c/o L. F. Carson, 504 Cavitt Ave., Trafford, Pa.
Carter, Ray K., 1311 Republic Bank Bldg., Dallas, Tex.
Cash, Harvey, Jr., Geop. Div., Texas Co., Box 2332, Houston, Tex.
Caster, E. L., Arkansas Natural Gas Corp., Box 1734, Shreveport, La.
Cerveny, Philip F., Box 2038, Pittsburgh, Pa.
Chandler, Lyman, Jr., c/o National Geophysical Co., Columbus, Miss.
Charske, C. J., Jr., 4222 Avondale Ave., Dallas, Tex.
*Child, V. E., Box 2332, Houston, Tex.
Christie, Norman J., 1255 E. Green St., Pasadena, Calif.
Clark, Charles Lindsey, 2114 N. Harwood St., Dallas, Tex.
Clark, R. C., P. O. Box 801, Tulsa, Okla.
Clark, R. W., 1260 Subway Terminal Bldg., Los Angeles, Calif.
*Clayton, Neal, P. O. Box 132, Ripley, Miss.
Clement, Paul F., P. O. Box 1468, Bakersfield, Calif.
Clifford, O. C., Jr., 2415 Sunset, Houston, Tex.
Cloud, Raymond T., 1216 S. Sandusky St., Tulsa, Okla.
Cobb, Howard L., Box 491, Hanover, N. H.
Coffin, R. Clare, 1204 E. 30th Place, Tulsa, Okla.
*Coit, R. B., N. P. P. M., Medan O. R. Sumatra, N. E. I.
Collingwood, Douglas M., c/o Sun Oil Co., Box 2880, Dallas, Tex.
*Constantinescu, M., Soc. Unirea, Ploesti, Roumania
Cook, D. E., Box 2038, Pittsburgh, Pa.
*Cooke, John G., Jr., c/o Arkansas-Louisiana Gas Co., Slattery Bldg., Shreveport, La.
Cooper, Jack R., 1311 Republic Bank Bldg., Dallas, Tex.
Copeland, Jefferson L., address unknown
*Copeland, R. J., P. O. Box 2038, Pittsburgh, Pa.
Cortes, Henry C., Box 900, Dallas, Tex.
Coursey, Walter D., 1921 N. Prairie, Dallas, Tex.
Courtier, William H., Geop. Dept., Phillips Petroleum Co., Bartlesville, Okla.
Cowles, Laurence G., 1406 Castle Court, Houston, Tex.
*Cox, Charles B., 202 Irving St., Denver, Colo.
Cox, Harris, 1311 Republic Bank Bldg., Dallas, Tex.
Craig, Robert L., c/o Standard Oil Co. of New Jersey, Postbox 392, The Hague, Holland
Crain, Ashton, c/o Arkansas Fuel Oil Co., Shreveport, La.
Cram, Ira H., Pure Oil Co., 35 E. Wacker Drive, Chicago, Ill.
Crandall, K. H., 2340 Robinhood, Houston, Tex.
Crary, Albert P., 2011 Esperson Bldg., Houston, Tex.
Crawford, John M., 1105 S. 9th, Ponca City, Okla.
Crawford, Paul D., 1426 Milam Bldg., San Antonio, Tex.
Cross, J. W., Humble Oil and Refg. Co., Houston, Tex.
Crowell, J. H., 2011 Esperson Bldg., Houston, Tex.
Culbertson, J. A., Box 3126, Houston, Tex.
Curnutt, F. E., c/o Tropical Oil Co., Barranca Bermeja, Colombia, S. A.
*Curtsinger, G. W., address unknown

*Dacus, A. C., 701 Waugh Drive, Houston, Tex.

*Dahlberg, Jack K., N. K. P. M., Soengei Gerong, Palembang, Sumatra, N. E. I.
Dahlberg, R. S., Jr., 1933 E. 14th St., Tulsa, Okla.
Dahm, C. G., 4609 Southern Ave., Dallas, Tex.
Dana, Drexler, Route 3, Box 280A, Bakersfield, Calif.
Dana, R. H., P. O. Box 48, Dodge City, Kan.
*Davenport, George, 2400 Red River, Austin, Tex.
*Davenport, Robert, Box 2040, Tulsa, Okla.
*Davies, Nathan C., Box 146, Fairfield, Ill.
Davies, Richard, c/o Anglo-Iranian Oil Co., Finsbury Circus, Britannic House, London, E. C. 2, England
Davis, Donald M., Pure Oil Co., Esperson Bldg., Houston, Tex.
*Davis, E. O., Nederlandsche Pacific Pet. Mij., Paleisweg 33, Medan, Sumatra, N. E. I.
*Day, Charles E., Box 2040, Tulsa, Okla.
*De Blank, B., B. P. M., Balik Papan, D. E. I.
*de Bruyn, J. W., c/o Burmah Shell Oil Co., Ltd., Karachi, India
†De Golyer, E. L., 611 Continental Bldg., Dallas, Tex.
DeGood, R. G., P. O. Drawer 2038, Pittsburgh, Pa.
DeLoach, Edward L., 1742 Milam Bldg., San Antonio, Tex.
Denning, Wayne H., 1915 First St., Bakersfield, Calif.
de Pijper, T., Sarawak Oilfields, Ltd., Miri via Singapore
Desmond, Jack M., Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
Deussen, Alexander, 1006 Shell Bldg., Houston, Tex.
*Dexter, Laurence N., c/o National Geophysical Co., Dallas, Tex.
Dickey, Calvin A. L., Box 4, Apt. 58 Baron Empian, Heliopolis, Cairo, Egypt
Dietert, Arthur E., 705 Masonic Empire Bldg., Bartlesville, Okla.
*Dissler, Ernest, 815 Sixteenth, Golden, Colo.
Diveley, Paul R., P. O. Drawer 2038, Pittsburgh, Pa.
Dix, C. H., Room 1137, 26 Broadway, New York, N. Y.
Doan, Richard L., 1337 Cherokee, Bartlesville, Okla.
*Dobrin, Milton B., P. O. Drawer 2038, Pittsburgh, Pa.
Dobyns, D. R., 721 Browder St., Dallas, Tex.
Doering, John, 3301 Southwestern, Dallas, Tex.
Dombart, William F., Box 2038, Pittsburgh, Pa.
Donnally, Chester J., 601 W. 5th St. #711, Los Angeles, Calif.
*Doss, C. L., 1702 Tower Petroleum Bldg., Dallas, Tex.
Douglas, Norvel, 220 West 42nd St., New York, N. Y.
Dresbach, C. H., Box 2038, c/o Gulf Research and Development Co., Pittsburgh, Pa.
Dreyfus, Robert M., Box 2038, Pittsburgh, Pa.
Duncan, J. E., 970 McMillan Ave., Winnipeg, Manitoba, Canada
*Dunlap, A. D., 2011 Esperson Bldg., Houston, Tex.
Dunlap, Robert C., Jr., 1311 Republic Bank Bldg., Dallas, Tex.
Durham, Charles A., 850 Humble Bldg., Houston, Tex.
*Durrett, H. D., 2011 Esperson Bldg., Houston, Tex.
Duty, Robert S., Jr., Humble Oil and Refining Co., Houston, Tex.
Dyk, Karl, Geop. Lab., Box 591, Tulsa, Okla.

Eby, A. N., Superior Oil Co., Seismograph Party #5, Oil and Gas Bldg., Houston, Tex.
Eby, J. Brian, P. O. Box 962, Houston, Tex.
Eckhardt, E. A., P. O. Drawer 2038, Pittsburgh, Pa.
*Egan, Daniel G., N. K. P. M., Geol. Dept., Soengei Gerong, Sumatra, N. E. I.
Eichelberger, A. M., Jr., 157 South E St., San Bernardino, Calif.
Eisler, Jospeh D., Stanolind Geophysical Laboratory, Box 591, Tulsa, Okla.
*Elam, Daniel F., P. O. Box 392, Great Bend, Kan.
Elkins, Thomas A., 3255 Parkview Ave., Pittsburgh, Pa.
Ellis, L. G., Sun Oil Co., Beaumont, Tex.
Ellsworth, Elmer W., 129 N. Maple, Centralia, Ill.
Ellsworth, T. P., 212 Van Sicklen Ave., Hanford, Calif.
Elms, R. G., 1311 Republic Bank Bldg., Dallas, Tex.
Emanuel, Vincent, c/o Azienda Generale Italiana Petroli, Via Roma 4, Casalpusterlengo (Milano), Italy

Emrick, D. G., P. O. Box 661, Tulsa, Okla.
England, C. M., Box 2040, Tulsa, Okla.
English, Walter A., 114 S. Beaudry Ave., Los Angeles, Calif.
*Epperson, R. S., 202 Humble Bldg., Houston, Tex.
Erickson, Anton, Continental Oil Co., Geop. Dept., Ponca City, Okla
Ericson, Harry B., 1215 Jennings Ave., Bartlesville, Okla.
*Ervin, C. H., Box 210, Palestine, Tex.
*Ervin, Lynn, P. O. Box 565, Edna, Texas.
Etherington, Thomas J., Richmond Petroleum Co. of Colombia, Aptdo. Nacional #2760, Aptdo. Aereo #3631, Bogota, Colombia, S. A.
Evans, Eugene P., Box 2040, Tulsa, Okla.
Evinger, H. H., 7455 Pennfield St., Pittsburgh, Pa.
Evjen, H. M., 3705 Bellaire, Houston, Tex.
Ewing, Maurice, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Fain, Edgar A., c/o Geophysical Service, Inc., 1311 Republic Bank Bldg., Dallas, Tex.
Falkenhagen, H. M. 2011 Esperson Bldg., Houston, Tex.
*Faris, J. P., Jr., Second Lieutenant, Engineering Reserves, Ft. Sam Houston, Tex.
Farren, Paul, National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
Farris, E. A., Jr., 5810 Worth St.(?), Dallas, Tex.
Faust, L. Y., Box 2040, Tulsa, Okla.
Fecht, Arthur J., 611 Esperson Bldg., Houston, Tex.
Ferber, Herbert J., c/o Western Gulf Oil Co., P. O. Box 1468, Bakersfield, Calif.
Ferguson, J. G., 909 Shell Bldg., Houston, Tex.
Ferguson, John L., Amerada Petroleum Co., Box 2040, Tulsa, Okla.
*Ferguson, W. S., 2011 Esperson Bldg., Houston, Tex.
Ferrick, James H., P. O. Box 2038, Pittsburgh, Pa.
Ferris, Craig, 909 Shell Bldg., Houston, Tex.
Fetzer, E. L., c/o National Geophysical Co., 1001 Tower Petroleum Bldg., Dallas, Tex.
Fisch, W., Stockerstr. 43, Zurich, Switzerland
*Fischer, L. F., Box 1451, Meridian, Miss.
Fisher, Barney, 406 Continental Bldg., Dallas, Tex.
Fisher, E. W., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Fleishman, Sam, 312 Professional Bldg., Bakersfield, Calif.
*Flournoy, Murray B., Box 2040, Tulsa, Okla.
Flude, J. W., Southern Plastic Co., 1500 Heiner St., Houston, Tex.
Fohs, F. Julius, 923 Esperson Bldg., Houston, Tex.
Foster, Edward S., Jr., c/o Halliburton Oil Well Cementing Co., Houma, La.
*Fraker, C. L., Box 2040, Tulsa, Okla.
Franks, W. E., Exploration Dept., Standard Oil Co. of Venezuela, Aptdo. 1329, Caracas, Venezuela, S. A.
Freel, J. F., 202 Humble Bldg., Houston, Tex.
Freeman, L. I., Heiland Research Corp., 727 Giddens-Lane Bldg., Shreveport, La.
Frosch, Alex, 254B Humble Bldg., Houston, Tex.

Gabriel, V. G., 290 S. Michigan, Pasadena, Calif.
Gaby, Edwin D., 519 Lampton Bldg., Jackson, Miss.
Gaby, Phil P., Box 134, Bakersfield, Calif.
Gahagan, Donald I., 2825 Quenby Road, Houston, Tex.
Gallaway, Roy Lee, #3 Sharia Birgas, Garden City, Cairo, Egypt
*Gallie, J. F., P.O. Box 777, Austin, Tex.
Gardner, Derry H., 269 Humble Bldg., Houston, Tex.
Gardner, Louis W., Drawer 2038, Pittsburgh, Pa.
Garrett, George A., 2011 Esperson Bldg., Houston, Tex.
†Garrett, L. P., Box 2100, Houston, Tex.
*Garrett, William M., 3614 Nottingham, Houston, Tex.
Gay, Andrew H., 637 Canal Bank Bldg., New Orleans, La.
Gayman, W. H., 235 N. Grinnell Drive, Burbank, Calif.
Gealy, Wendell B., P. O. Drawer 2038, Pittsburgh, Pa.
*Gemmell, Howard F., Gulf Research and Development Corp., P. O. Box 2038, Pittsburgh, Pa.

Gemmer, R. W., Carter Oil Co., Box 801, Tulsa, Okla.
Gerdes, C. H., Socony-Vacuum Oil Co., C. A., Aptdo. 246, Caracas, Venezuela, S. A.
Gerlough, Daniel L., 909 Shell Bldg., Houston, Tex.
Germain-Jones, D. T., Lanehead, Butley Town, Prestbury, Cheshire, England
Gibbon, H. A., 26 Broadway, New York, N. Y.
Gibson, M. O., 1124 Bomar, Houston, Tex.
Gill, W. D., P. O. Drawer 2061, San Antonio, Tex.
*Gilliam, J. T., Box 2040, Tulsa, Okla.
Gilliland, J. R., Stanolind Oil and Gas Co., Seis. Dept., Box 591, Tulsa, Okla.
Gillin, John A., 4501 N. Versailles, Dallas, Tex.
Gilmore, Homer, 286 C. of C. Bldg., Los Angeles, Calif.
Gilmour, Andrew, Box 2040, Tulsa, Okla.
Goebel, Lawrence A., Box 237, Jena, La.
Golden, John M., 2011 Esperson Bldg., Houston, Tex.
Goldstone, Frank, Shell Oil Co., Inc., Houston, Tex.
*Gomez, J. S., c/o Mott-Smith Corp., 909 Shell Bldg., Houston, Tex.
Goss, Henry V., Humble Oil and Refg. Co., 861 Humble Bldg., Houston, Tex.
Gossage, R. J., 32, Garrick Road, Northampton, England
Gould, Martin J., c/o Stanolind Oil and Gas Co., Geop. Res. Dept., Tulsa, Okla.
Green, Cecil H., 1311 Republic Bank Bldg., Dallas, Tex.
Green, W. G., Seismograph Service Corp., 709 Kennedy Bldg., Tulsa, Okla.
Griffin, I. M., Jr., 203 Hopkins Bldg., Bakersfield, Calif.
*Grizzell, Edward I., 2011 Esperson Bldg., Houston, Tex.
*Gunn, J. E., Drawer 2038, Pittsburgh, Pa.
*Guseman, L. F., Box 2332, Houston, Tex.
Gutenberg, Beno, Seismological Laboratory, 220 N. San Rafael Ave., Pasadena, Calif.

Haber, A. F., c/o Continental Oil Co., Ponca City, Okla.
Hafner, W., c/o Shell Oil Co., Shell Bldg., Houston, Tex.
*Haight, H. W., Standard Oil Co. of Egypt, 22, Sharia Kasr el Nil, Cairo, Egypt
Hale, Donald H., 2601 Grant St., Houston, Tex.
Hall, Hubert N., Box 1211, Tulare, Calif.
Halliday, O. T., 202 Humble Bldg., Houston, Tex.
*Hamic, Claude P., 701 Waugh Drive, Houston, Tex.
Hamilton, W. B., c/o Louisiana Land and Exploration Co., Houma, La.
Hammer, Sigmund I., P. O. Box 2038, Pittsburgh, Pa.
Handley, E. J., Geop. Div., Continental Oil Co., Ponca City, Okla.
Harding, Maynard W., c/o United Geophysical Co., 1255 E. Green St., Pasadena, Calif.
Harding, R. L., 709 Kennedy Bldg., Tulsa, Okla.
Hardy, Willis W., Socony-Vacuum Oil Co., Room 1137, 26 Broadway, New York, N. Y.
*Hargis, A. V., Birthright, Texas
*Harkey, W. J., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Harkins, Curtis P., 2011 Esperson Bldg., Houston, Tex.
Harkins, T. I., 2011 Esperson Bldg., Houston, Tex.
*Harlton, Bruce H., Box 2040, Tulsa, Okla.
Harrington, G. H., Barnsdall Oil Co., Houston, Tex.
Harris, B. A., National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
Harris, Sidon, c/o Stanolind Oil and Gas Co., Box 1410, Ft. Worth, Tex.
*Harris, Stevens T., Jr., 2211 Red River St., Austin, Tex.
Haskell, Norman A., c/o Western Geophysical Co., 16 Crites Bldg., Bakersfield, Calif.
Hastings, W. K., P. O. Drawer 2038, Pittsburgh, Pa.
*Hatch, J. D., 256 Humble Bldg., Houston, Tex.
Hawkins, J. E., c/o Heiland Research Corp., 700 Club Bldg., Denver, Colo.
Hawley, Paul F., Stanolind Oil and Gas Co., 418 Philcade Bldg., Tulsa, Okla.
Haynes, C. J., 256 Humble Bldg., Houston, Tex.
*Head, E. I., P. O. Box 346, Russellville, Ala.
Heard, Burton E., 5102 Vickery St., Dallas, Tex.
Hedeman, W. R., Jr., National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Hedstrom, A. A., c/o Burnett Sanitarium, Fresno, Calif.
Heggblom, J. C., Box 1089, Fresno, Calif.

*Heggy, Homer L., address unknown
Heiland, C. A., Dept. of Geophysics, Colorado School of Mines, Golden, Colo.
Henderson, Homer I., McCollum Exploration Co., 611 Esperson Bldg., Houston, Tex.
Henderson, Paul V., 1702 Tower Petroleum Bldg., Dallas, Tex.
Henquet, R., 533 Jergins Trust Bldg., Long Beach, Calif.
Herald, Frank B., 229 S. Camden Drive, Beverly Hills, Calif.
Herzenberg, A. J., 3705 Bellaire Blvd., Houston, Tex.
*Heyer, George S., Box 1192, Houston, Tex.
Hibbler, Alfred J., Texas Co., Box 2332, Houston, Tex.
Hibbler, M. E., Box 2332, Houston, Tex.
*Hieatt, Herbert F., 1912 N. St. Paul St., Dallas, Tex.
*Higgins, G. E., Caracas Petroleum S. A., Aptdo. 89, Caracas, Venezuela, S. A.
Hightower, C. H., 2725 Vickery Blvd., Ft. Worth, Tex.
*Hillis, Donuil, 785 Market St., San Francisco, Calif.
Hillyer, Ray H., 1914 South Blvd., Houston, Tex.
Hintze, A. J., 1200 Keeler, Bartlesville, Okla.
Hoard, J. O., 618 Esperson Bldg., Houston, Tex.
*Hodgson, John H., c/o Schlumberger Well Surveying Corp., Jergins Trust Bldg., Long Beach, Calif.
*Hoffman, John C., 631 Naomi Ave., Arcadia, Calif.
Hoffman, Malvin G., 1321 S. Quaker Ave., Tulsa, Okla.
Hogg, W. B., National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
Holland, Aaron E., 2011 Esperson Bldg., Houston, Tex.
Holland, Sam B., 256 Humble Bldg., Houston, Tex.
Hollingsworth, W. E., 1655 Ave. C, Beaumont, Tex.
Hollobaugh, Robert C., Box 2038, Pittsburgh, Pa.
Honnell, P. M., E. E. Dept., Southern Methodist University, Dallas, Tex.
Hoover, Herbert, Jr., 500 Sierra Madre Ave., Sierra Madre, Calif.
Hoover, J. W., c/o California Co., 1500 Petroleum Bldg., Houston, Tex.
*Hopkins, James S., Box 2040, Tulsa, Okla.
Horn, J. W., Arkansas-Louisiana Gas Co., Shreveport, La.
Horton, Claude Wendell, Box 2099, Houston, Tex.
Horton, H. M., 629 E. Powell Ave., Evansville, Ind.
Horvitz, Leo, 701 Waugh Drive, Houston, Tex.
*Hotard, A. A., Box 443, Rosenberg, Tex.
Houghton, H. M., Box 2040, Tulsa, Okla.
Houston, Charles E., 825 Humble Bldg., Houston, Tex.
Howard, G. C., Box 1739, Shreveport, La.
Howell, Lynn G., Box 2180, Houston, Tex.
Howerton, Bert P., Box 47, Corpus Christi, Tex.
Hoylman, H. Wayne, 3057 Richmond Blvd., Oakland, Calif.
Hubbard, Bela, c/o Standard Oil Co. of New Jersey, Producing Dept., 30 Rockefeller Plaza, New York, N. Y.
Hubner, B. G., Jr., Seis. Party #1, Atlantic Refg. Co. of Cuba, 15, Pinar del Rio, Prov. de Pinar del Rio, Cuba
Hughes, Darrell S., P. O. Box 2099, Houston, Tex.
Hughes, Roland F., Continental Oil Co., Geop. Dept., Ponca City, Okla.
Hull, J. W., 6123 Magnolia Ave., Riverside, Calif.
Hunsaker, Neville C., 2309 Delafield, Houston, Tex.
Hunzicker, A. A., Box 2332, Houston, Tex.
Hurry, Clare N., Box 801, Tulsa, Okla.
Hurt, W. B., Magnolia Petroleum Co., Dallas, Tex.

Imle, Harry R., Box 697, Ardmore, Okla.
Imle, John F., c/o Petty Geophysical Engineering Co., 317 Sixth St., San Antonio, Tex.
Innes, Arland I., Box 2040, Tulsa, Okla.
*Irby, W. L., 256 Humble Bldg., Houston, Tex.
Ittner, Frank, 1425 Union, Box 96, Bakersfield, Calif.
Ivy, John S., Union Producing Co., Shreveport, La.

Jackson, G. L., Humble Oil and Refg. Co., Houston, Tex.

Jackson, J. B., P. O. Box 760, Rangoon, Burma
Jackson, Ralph S., 2011 Esperson Bldg., Houston, Tex.
*Jackson, Robert W., 4512 Swiss Ave., Dallas, Tex.
Jakosky, J. J., 1120 W. 11th St., Lawrence, Kan.
*Jameson, M. H., 12 Kay Terrace, Rochester, N. Y.
Jaques, Alvin T., 2013 Cresline, Houston, Tex.
*Jasinski, Edward J., Atlantic Refg. Co. of Cuba, Aptdo. 5, Los Palacios, Pinar del Rio, Cuba
*Jerome, J. Glen, 2011 Esperson Bldg., Houston, Tex.
Jett, J. E., 1702 Tower Petroleum Bldg., Dallas, Tex.
Johnson, Curtis H., 1136 Franklin St., Santa Monica, Calif.
*Johnson, E. W., Box 278, Decatur, Tex.
*Johnson, L. H., 608 S. Penn St., Denver, Colo.
*Johnston, Frank M., Box 487, Rawlins, Wyo.
Johnston, T. F., E. E. Dept., Iowa State College, Ames, Iowa
Jones, John H., Gulistan Ganghill, Guildford, Surrey, England
Jones, M. P., 1311 Republic Bank Bldg., Dallas, Tex.
Jones, Ralph E., Box 2038, Pittsburgh, Pa.
Jonsson, J. E., 1311 Republic Bank Bldg., Dallas, Tex.
*Jordan, C. K., Geop. Dept., Continental Oil Co., Ponca City, Okla.
Judson, J. F. c/o Socony-Vacuum Oil Co., Aguas Claras, Puerto Wilches, Santander, Colombia, S. A.
Judson, Sidney A., Box 2199, Houston, Tex.
Jurin, Boris M., 4329 Gateway Ave., Los Angeles, Calif.

Kaiser, George B., Wharton, Tex.
Kannenstine, Fabian M., 2011 Esperson Bldg., Houston, Tex.
Karcher, J. C., 406 Continental Bldg., Dallas, Tex.
Kauenhowen, Walter, Deutsche Vakuum Oel A. G., Spitalerstrasse 12, IV, Hamburg 1, Germany
Kaufmann, G. F., Aptdo. 1329, Caracas, Venezuela, S. A.
*Kamen-Kaye, M., Aptdo. 89, c/o Caracas Pet. Corp., Caracas, Venezuela, S. A.
Kearby, J. G., 1041 Liberty Bank Bldg., Dallas, Tex.
Kearns, B. E., 126½ N. Canyon, Carlsbad, New Mexico
Kelly, Sherwin F., Geophysical Explorations Ltd., 330 Bay St., Toronto, Canada
Kendall, G. D., Box 2040, Tulsa, Okla.
Kendall, James M., 1948 N. Boston Ave., Tulsa, Okla.
Kendall, W. B., Box 2040, Tulsa, Okla.
Kennedy, Frank H., Jr., 1702 Tower Petroleum Bldg., Dallas, Tex.
*Kennedy, Kenneth K., Box 108, New Plymouth, New Zealand
Kerbow, R. B., P. O. Drawer 2038, Pittsburgh, Pa.
Kerns, A. D., 2513 Gulf Bldg., Houston, Tex.
Kerns, G. P., 510 S. Magnolia, Palestine, Tex.
Kerr, Richard C., C. A. S. O. C., Bahrein Island, Persian Gulf, via: London-Baghdad
Kidd, Robert L., Cities Service Oil Co., Bartlesville, Okla.
*Kiesler, Ernest A., 1311 Republic Bank Bldg., Dallas, Tex.
*Kilborn, J. M., 509 St. Clair St. (Box 346), Russellville, Ala.
*Kimble, Henry R., c/o Socony-Vacuum Oil Co., Aptdo. 246, Caracas, Venezuela, S. A.
Klaus, H., Box 1617, Lubbock, Tex.
Klipsch, Paul W., 701 Waugh Drive, Houston, Tex.
Koenig, Palmer E., 23–24 Metropolitan Bldg., Centralia, Ill.
Koenigsberger, J. G., Steinau i Odenwald, Germany
Konkel, Philip M., c/o Ohio Oil Co., Marshall, Ill.
Konz, Leo W., 908 W. 19th, Austin, Tex.
Krahmann, Rudolf, P. O. Box 1167, Johannesburg, South Africa
*Kretz, Robert L., 1500 Petroleum Bldg., Houston, Tex.

Ladner, A. L., 3416 Palm, Houston, Tex.
Lake, J. L., 701 Waugh Drive, Houston, Tex.
Lamb, George B., P. O. Drawer 2100, Houston, Tex.

*Langley, R. M., 701 Waugh Drive, Houston, Tex.
LaRue, James E., Box 2180, Houston, Tex.
LaRue, Wilton W., 2339 Wroxton Road, Houston, Tex.
Lash, Charles C., 1402 N. Harris, Hanford, Calif.
*Latimer, M. W., 506 Joplin National Bank Bldg., Joplin, Mo.
Lawhorn, O. T., 1311 Republic Bank Bldg., Dallas, Tex.
Lawrence, K. M., c/o Geophysical Research Corp., Box 2040, Tulsa, Okla.
Lay, Roy L., Box 2332, Houston, Tex.
*Lea, W. T., Arkansas Fuel Oil Co., Shreveport, La.
Le Conte, Joseph, 312 Professional Bldg., Bakersfield, Calif.
Lee, B. D., Texas Co. (Venezuela) Ltd., Aptdo. #267, Caracas, Venezuela, S. A.
Lee, Walter B., Jr., Drawer 2038, Pittsburgh, Pa.
Leedy, F. B., Yacimientos Petroliferos Fiscales, Departmento Mineria y Geologia, Seccion Sismografica, Diag. Roque Saenz Pena 777, Buenos Aires, Argentina, S. A.
Legge, J. A., Jr., c/o Richmond Pet. Co., Edificio Chavijo Carrera 6a; Con Calle 15, #14–50, Bogota, Colombia, S. A.
*Lehman, Frank F., P. O. Box 2038, Pittsburgh, Pa.
*Lemke, Ernest W., c/o Carter Oil Co., Box 252, Aberdeen, Miss.
Leonardon, E. G., 2720 Leeland Ave., Houston, Tex.
Lester, John A., 721 Browder St., Dallas, Tex.
Lester, O. C., Jr., Box 2040, Tulsa, Okla.
Lewis, Karl E., 1702 Tower Petroleum Bldg., Dallas, Tex.
Lewis, William Bradley, Humble Oil and Refg. Co., Houston, Tex.
Levings, W. S., 5730 Montview Blvd., Denver, Colo.
*Lipson, Edward, 1111 Eagle Ave., Houston, Tex.
Lohman, R. W., 416 Grand Ave., S. Pasadena, Calif.
Lohse, John M., 256 Humble Bldg., Houston, Tex.
Long, Clarence J., P. O. Box 591, Tulsa, Okla.
*Long, John V., 4120 5th Ave., San Diego, Calif.
*Loring, Ralph C., c/o International Pet. Co. Ltd., Aptdo. 803, Guayaquil, Ecuador, S. A.
Lovejoy, J. B., P. O. Box 1290, Ft. Worth, Tex.
*Lovinggood, Toby, Paleisweg 33, Medan, Sumatra, N. E. I.
*Lowe, C. R., 2820 Edgar St., Shreveport, La.
*Loy, Milton E., 439 S. Peck Drive, Beverly Hills, Calif.
Lukens, John P., 1311 Republic Bank Bldg., Dallas, Tex.
Lundberg, Hans, 80 Richmond St. W., Toronto, Ontario, Canada
Lynn, Ralph D., 1716 E. 14th St., Tulsa, Okla.
Lynton, Edward D., P. O. Drawer 430, Whittier, Calif.
Lyons, Richard T., Tide Water Associated Oil Co., 708 Esperson Bldg., Houston, Tex.

MacAllister, C. T., 510 S. Magnolia St., Palestine, Tex.
Macelwane, James B., S. J., 15 N. Grand Blvd., St. Louis, Mo.
Mackey, C. L., address unknown
MacMahon, A. M., 2501 Southmore Blvd., Houston, Tex.
MacNaughton, Lewis W., 611 Continental Bldg., Dallas, Tex.
Malamphy, Mark C., 414 Goethe St., Cumberland, Md.
*Malcher, Kurt, Aptdo. 2053, Mexico City, D. F., Mex.
Maliphant, H. C., c/o B. P. M. (G. A.), Balik Papan, Borneo, N. E. I.
Manes, O. B., 2011 Esperson Bldg., Houston, Tex.
Manhart, T. A., 712 Kennedy Bldg., Tulsa, Okla.
Mann, Neil W., c/o C. A. S. O. C., Seismo. #1, Bahrein Island, Persian Gulf, via Baghdad-Iraq, Overland Route
Mannes, W. H., 1937 Lexington Ave., Houston, Tex.
*Manning, A. B., 2244 Birch St., Denver, Colo.
*Manning, Earl L., 2011 Esperson Bldg., Houston, Tex.
Manning, W. G., 2011 Esperson Bldg., Houston, Tex.
Mansfield, Robert H., c/o United Geophysical Corp., 1255 E. Green St., Pasadena Calif.
Mariner, R. E., Jr., P. O. Drawer 2061, Petty Geophysical Engineering Co., San Antonio, Tex.

*Markstein, Georg, Calle 35, No. 17/21, Bogota, Colombia, S. A.
Markwardt, E. W., 1702 Tower Petroleum Bldg., Dallas, Tex.
Marr, John D., 1722 Rice Blvd., Houston, Tex.
Marsh, Samuel R., Box 801, Tulsa, Okla.
Marti, J. E., 2011 Esperson Bldg., Houston, Tex.
*Martin, Dick, Dynamite Depot, Route #3, Tulsa, Okla.
*Martin, Sidney A., Jr., Box 610, Kingsville, Tex.
Mason, C. C., 256 Humble Bldg., Houston, Tex.
*Mason, Jack, Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
Mathews, John W., 530 Ash Ave., Bakersfield, Calif.
Maxwell, E., Box 2099, Houston, Tex.
Maxwell, Joseph M., 4th floor Higgins Bldg., Los Angeles, Calif.
Mayfield, W. I., Petty Geophysical Engineering Co., Box 2061, San Antonio, Tex.
McAlister, C. H., Petty Geophysical Engineering Co., San Antonio, Tex.
*McAllen, W. J., 374 South Ave., Glencoe, Ill.
McBurney, Charles G., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*McCaleb, M. M., 256 Humble Bldg., Houston, Tex.
McCartney, Reed L., 2011 Esperson Bldg., Houston, Tex.
McCloskey, Downs, c/o Amerada Pet. Corp., 417 S. Hill St., Los Angeles, Calif.
McCollum, Burton, 611 Esperson Bldg., Houston, Tex.
McCollum, Elton V., 909 Shell Bldg., Houston, Tex.
McCracken, Guy I., P. O. Box 2038, Pittsburgh, Pa.
*McCready, H. J., c/o T. F. Roche, Aptdo. Aereo #32, Barranquilla, Colombia, S. A.
McDermott, Eugene, 1311 Republic Bank Bldg., Dallas, Tex.
McGee, John E., Box 2038, Pittsburgh, Pa.
McGhee, George C., Continental Bldg., Dallas, Tex.
*McGinity, J. V., 401 W. 1st St., Tulsa, Okla.
McGrady, Dupree, c/o Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
*McKanna, Edwin A., 801 Columbia St., S. Pasadena, Calif.
McKay, A. E., Box 871, Midland, Tex.
McLaren, R. L., Box 1734, Arkansas Natural Gas Corp., Shreveport, La.
McLarry, Weldon G., 701 Waugh Drive, Houston, Tex.
McLemore, Ethel Ward, 4119 Boaz, Dallas, Tex.
*McMullin, E. F., Woodsboro, Tex.
McNatt, E. M., Carter Oil Co., Tulsa, Okla.
*Meador, Bernal M., Casilla 803, Guayaquil, Ecuador, S. A.
*Meitzen, J. B., Box 1273, Mobile, Ala.
Melton, Ben S., 1001 Tower Petroleum Bldg., Dallas, Tex.
Melton, E. Roane, 2038 Norfolk, Houston, Tex.
Menefee, James C., 721 Browder St., Dallas, Tex.
*Merion, G. Ralph, Geochemical Div., Humble Oil and Refg. Co., Houston, Tex.
Merritt, H. W., 1523 Marshall St., Houston, Tex.
Merritt, W. C., Standard Oil Co. of Venezuela, Exploration Dept., Aptdo. 1329, Caracas, Venezuela, S. A.
*Meszaros, W. A., P. O. Drawer 2038, Pittsburgh, Pa.
Metcalf, D. F., Jr., Geophysical Dept., Humble Oil and Refg. Co., Houston, Tex.
Meyer, Edgar J., Box 2038, Pittsburgh, Pa.
Miller, Arthur B., 869 Humble Bldg., Houston, Tex.
Miller, R. D., Geop. Dept., Shell Oil Co., Inc., Houston, Tex.
Miller, Vincent, Geol. Dept., Phillips Pet. Co., Bartlesville, Okla.
*Millet, M. J., Texaco Development Corp., Box 2332, Houston, Tex.
Milstein, Mark N., 53 Ross St., Toorak, S. E. 2, Melbourne, Vic. Australia
Minton, J. P., Magnolia Petroleum Co., 721 Browder St., Dallas, Tex.
†Mintrop, L., Schlosplatz 2, Breslau, Germany
Minturn, L. W., Tropical Oil Co., El Centro, Colombia, S. A.
Mitchell, George D., Jr., 3118 Nottingham, Houston, Tex.
Mitera, Z. A., Ul. Fredry 7. m. 9., Lwow, Russia
Mix, Adrian E., Aptdo, 246, Caracas, Venezuela, S. A.
Montgomery, George P., 256 Humble Bldg., Houston, Tex.
Moody, Herbert H., Geop. Dept., Continental Oil Co., Ponca City, Okla.

Moon, Jake, 1311 Republic Bank Bldg., Dallas, Tex.
Moore, Arthur A., Jr., 256 Humble Bldg., Houston, Tex.
Moore, Charles M., 4411 Glenwood, Dallas, Tex.
Moore, Homer C., P. O. Box 2332, Houston, Tex.
*Moore, Horace S., P. O. Box 2313, Manila, Philippine Islands
Moore, James A., c/o Union Sulphur Co., Sulphur, La.
*Moore, Marion J., P. O. Box 88, Transwestern Oil Co., San Antonio, Tex.
Moore, W. Lee, Jr., P. O. Box 2061, San Antonio, Tex.
Moorman, H. R., 1137 26 Broadway, New York, N. Y.
Moran, R. B., Jr., 1335 Olive Lane, La Canada, Calif.
Morgan, Charles Gill, United Geophysical Co., 1255 E. Green St., Pasadena, Calif.
*Morgan, Wesley H., 2011 Esperson Bldg., Houston, Tex.
*Morris, Euclid, 2011 Esperson Bldg., Houston, Tex.
Morris, James L., Box 2107, Ft. Worth, Tex.
Morris, Lawrence K., 1255 E. Green St., Pasadena, Calif.
Morrison, M. S., Aptdo. 31, Pasto, Narino, Republic of Colombia, S. A.
Morrow, Dallas C., 1311 Republic Bank Bldg., Dallas, Tex.
Mortlock, Frank O., Drawer 2038, Pittsburgh, Pa.
Mott-Smith, L. M., 1911 W. Alabama, Houston, Tex.
Mott-Smith, M., 5510 Chartres, Houston, Tex.
Mounce, W. D., Box 2180, Houston, Tex.
*Mount, E. L., Geop. Div., Continental Oil Co., Ponca City, Okla.
Muffly, Gary, Drawer 2038, Pittsburgh, Pa.
*Mullinax, Jack D., Continental Oil Co., Gecl. Div., Ponca City, Okla.
Muskat, Morris, Drawer 2038, Pittsburgh, Pa.
Muzzey, David S., Jr., 3705 Bellaire Blvd., Houston, Tex.
Myers, Clay K., c/o John G. Myers Co., Albany, N. Y.
*Myers, John R., 721 Browder St., Dallas, Tex.

Nahas, J. N., 1210 Ashley Ave., Beaumont, Tex.
Nash, C. C., Jr., c/o Carter Oil Co., Tulsa, Okla.
Nash, Paul E., 3629 Greenbrier Drive, Dallas, Tex.
*Navarte, P. E., Box 2061, San Antonio, Tex.
Neff, W. D., c/o General Geophysical Co., 2514 Gulf Bldg., Houston, Tex.
Neidert, John H., Seis. Div., Standard Oil Co. of Venezuela, Caripito, Venezuela, S. A.
Nettleton, L. L., Box 2038, Pittsburgh, Pa.
Neumann, G., c/o American Askania Corp., 826 M. & M. Bldg., Houston, Tex.
Neuman, L. J., 1520 Hawthorne, Houston, Tex.
Newby, C. J., 865 Humble Bldg., Houston, Tex.
Newton, W. W., 4416 University Blvd., Dallas, Tex.
Nichols, E. Turnley, N. V. Nederlandsche Nieuw-Guinee Pet. Mij., Paleisweg 33, Medan, Sumatra, N. E. I.
Nisle, Robert G., address unknown
Nomann, Arthur B., 1729 Meridian Ave., S. Pasadena, Calif.
*Norelius, Russell G., 1217 S. Alvocado (?), Los Angeles, Calif.
North, Willard, 417 S. Hill St., Los Angeles, Calif.
Northcutt, W. C., P. O. Box 1060, Tulare, Calif.
*Noser, W. P., 256 Humble Bldg., Houston, Tex.

O'Brien, Decatur, 256 Humble Bldg., Houston, Tex.
Oddone, Decio Saverio Rua Santa Amelia 35 (Mattoso), Rio de Janeiro, Brazil, S. A.
Odenweller, Keith H., Aptdo. 78, Cuidad Bolivar, Venezuela, S. A.
O'Donnell, T. J., c/o Mene Grande Oil Co. C. A., Aptdo. 45, Barcelona, Venezuela, S. A.
Olson, O. C., C. A. S. O. C., Bahrein Island, Persian Gulf
Osterhoudt, W. J., Drawer 2100, Houston, Tex.
*Owen, Ernest J., address unknown
Owen, J. E., 2607 N. Boston Place, Tulsa, Okla.

*Paddison, Louis J., Box 113, Sylvania Station, Ft. Worth, Tex.

Palmer, E. M., Box 2038, Pittsburgh, Pa.
Palmer, John E., 253 Humble Bldg., Houston, Tex.
Palmer, R. L., McCollum Exploration Co., 611 Esperson Bldg., Houston, Tex.
*Parker, L. A., 2011 Esperson Bldg., Houston, Tex.
Parkhurst, George L., Room 1602, 910 S. Michigan Ave., Chicago, Ill.
Paslay, L. C., 74 Edgewood St., Larchmont, N. Y.
Paterson, R. G., 718 6th Ave. W., Calgary, Alberta, Canada
Patrick, H. G., Box 2180, Houston, Tex.
Peacock, H. B., 825 Esperson Bldg., Houston, Tex.
*Pellillo, M. J., c/o National Geophysical Co., Goliad, Tex.
Perkins, B., Jr., Box 2038, Pittsburgh, Pa.
Perkinson, Floyd, Compania Consolidado de Petroleo, Aptdo. 1706, Caracas, Venezuela, S. A.
Pernell, J. H., 1002 Tower Petroleum Bldg., Dallas, Tex.
Perry, W. B., 120, North Philadelphia, Shawnee, Okla.
Perryman, J. D., c/o Geotechnical Corp., Dallas, Tex.
Peters, Leo J., Box 661, Tulsa, Okla.
Peterson, Raymond A., 1255 E. Green St., Pasadena, Calif.
Peterson, V. A., Geop. Div., Continental Oil Co., Ponca City, Okla.
Petty, Dabney E., No. 10 10th St., San Antonio, Tex.
Petty, O. S., P. O. Box 2061, San Antonio, Tex.
Pezdek, Victor J., P. O. Box 1468, Bakersfield, Calif.
Pirson, Sylvain J., School of Mineral Industries, State College, Pa.
Pittman, C. V. A., 1311 Republic Bank Bldg., Dallas, Tex.
Poindexter, Louis, 1311 Republic Bank Bldg., Dallas, Tex.
Pollard, J. C., P. O. Box 900, Dallas, Tex.
*Pollei, Donald W., 721 Browder St., Dallas, Tex.
Pope, Turner T., 2011 Esperson Bldg., Houston, Tex.
Postma, G. W., B. P. M., Sangasanga, Borneo, D. E. I.
Prade, Nat H., c/o Geop. Dept., Sun Oil Co., Beaumont, Tex.
Pranglin, John A., Lane-Wells Corp., P. O. Box 389, Corpus Christi, Tex.
Pratt, R. B., 5431 Vickery Blvd., Dallas, Tex.
†Pratt, W. E., 30 Rockefeller Plaza, New York, N. Y.
Pratley, H. Hart, 1331 No. Pacific Ave., Glendale, Calif.
Prescott, H. R., 703 McFadden, Ponca City, Okla.
Price, Wiley R., Jr., 4015 Second Ave., Los Angeles, Calif.

*Ramaccioni, D., Avenida Roque Saenz Pena 777, Buenos Aires, Argentina, S. A.
Ramsden, C. H., Standard Oil Co. of Venezuela, Maracaibo, Venezuela, S. A.
*Ransone, Keating, 701 Waugh Drive, Houston, Tex.
Ransone, W. R., 1311 Republic Bank Bldg., Dallas, Tex.
Ray, R. H., 2725 Pemberton Drive, Houston, Tex.
*Reagor, Edward C., 3804 Cedar Springs Road, Dallas, Tex.
*Reed, Charles F., Jr., Box 229, Long Beach, Calif.
Reed, Paul C., P. O. Box 209, Columbia, Miss.
Reel, C. E., 2605 Escuela Ave., Bakersfield, Calif.
*Reiser, Robert G., P. O. Box 2038, Pittsburgh, Pa.
Renner, Darwin S., P. O. Box 2703, Dallas, Tex.
Rey, Pedro, Dto. Exploration Y. P. F., 777 Diagonal Roque Saenz Pena, Buenos Aires, Argentina, S. A.
Reynolds, F. F., 2911 Gulf Bldg., Houston, Tex.
Rice, E. R., Jr., P. O. Box 900, Dallas, Tex.
Richards, T. C., c/o Burmah Oil Co., Ltd., Rangoon, Burma
Rickel, Wesley K., 421 W. Platte Ave., Ft. Morgan, Colo.
Ricker, Norman H., c/o Carter Oil Co., P. O. Box 801, Tulsa, Okla.
Rieber, Frank, 11916 W. Pico Blvd., Los Angeles, Calif.
Riess, Malcolm, Box 801, Tulsa, Okla.
*Riley, N. Allen, 2610 E. 73rd St., Chicago, Ill.
Ritzmann, O. F., P. O. Box 2038, Pittsburgh, Pa.
Roark, James J., Carter Oil Co., Box 1166, Warren, Ohio

Roberts, Francis A., c/o N. V. N. K. P. M., Soengei Gerong, Sumatra, N. E. I.
*Roberts, Homer E., Box 760, Rangoon, Burma
*Roberts, Louin W., c/o Mrs. G. T. Roberts, Blair, Okla.
Robinson, W. Bernard, Drawer 2038, Pittsburgh, Pa.
Rock, Sibyl M., c/o Mrs. William Lee, 423 N. Chandler St., Monterey Park, Calif.
Rodgers, P. A., 1201 Rigsby Ave., San Antonio, Tex.
Rojas, A. Garcia, Avda. Juarez 94, Gerencia de Produccion, Mexico, D. F., Mex.
Rollins, J. Frank, 1311 Republic Bank Bldg., Dallas, Tex.
*Rolshausen, F. W., c/o Humble Oil and Refg. Co., P. O. Box 2180, Houston, Tex.
Romberg, Frederick E., c/o Geophysical Service, Inc., 1241 Subway Terminal Bldg., Los Angeles, Calif.
*Romberg, M., c/o R. L. Suggs, Humble Seis. Crew, Geol. Dept., N. K. P. M., Soengei Gerong, Palembang, Sumatra, N. E. I.
Rosaire, Carol G., 701 Waugh Drive, Houston, Tex.
Rosaire, E. E., 701 Waugh Drive, Houston, Tex.
Rose, H. W., Sun Oil Co., Beaumont, Tex.
Ross, Charles M., Box 2040, Tulsa, Okla.
*Ross, J. D., P. O. Box 3404, Manila, Philippine Islands
Ross, R. B., P. O. Box 2038, Pittsburgh, Pa.
Rozlosnik, Andres, Cordoba 612, 6° Piso, Depto. A, Buenos Aires, Argentina, S. A.
Ruhlen, W. W., 420 S. Willow St., Pecos, Tex.
Rulfs, G. W., Jr., 1408 MacGregor Ave., Houston, Tex.
Rupnik, J. Joseph, 364 S. Hudson Ave., Pasadena, Calif.
Rusler, George W., Verona Road, Verona, Pa.
Rust, W. M., Jr., 2222 Shakespeare, Houston, Tex.
Rutherford, Homer M., P. O. Box 1023, Houston, Tex.
*Rutledge, Richard B., 706 Skelly Bldg., Box 1650, Tulsa, Okla.

Saibara, Robert, 701 Waugh Drive, Houston, Tex.
Salvatori, Henry, 711 Edison Bldg., Los Angeles, Calif.
Samuels, G. H., Jr., Cia de Petroleo Shell de Colombia, Colombia, S. A.
Sanders, C. W., 3428 Wickersham Lane, Houston, Tex.
Sandidge, Irl, Box 1112, Ft. Worth, Tex.
*Sargent, R. L., Amerada Petroleum Co., Box 2040, Tulsa, Okla.
Saunders, L. W., 2731 18th St., Bakersfield, Calif.
Saville, W. G., 1406 Shell Bldg., Houston, Tex.
Sawtelle, D. M., 1035 W. Kings Highway, San Antonio, Tex.
Sawyer, J. H., Cia de Pet. Shell de Colombia, Bogota, Colombia, S. A.
Schaeffer, Hugh C., 3416 NW 20th, Oklahoma City, Okla.
Schafer, Sidney, Tide Water Associated Oil Co., Houston, Tex.
Scharf, David, 2011 Esperson Bldg., Houston, Tex.
*Schiflett, H. L., P. O. Box 2332, Houston, Tex.
Schleusener, Ludwig Brunstrasse 17, Hannover, Germany
Schley, Woodruff H., 5704 Hudson St., Dallas, Tex.
Schlumberger, Marcel, c/o Compagnie Generale de Geophysique, 48, Boulevard La Tour Maubourg, Paris VII, France
*Schmidt, Henry, 2011 Esperson Bldg., Houston, Tex.
*Schmidt, Karl H., Jr., c/o Kadane, Inc., Wichita Falls, Tex.
Schmuck, R. H., Humble Oil and Refg. Co., Houston, Tex.
*Schneider, John E., Box 1723, Baton Rouge, La.
*Schoellhorn, Henry, III, Seismic #20, Gulf Res. & Dev. Co., P.O. Drawer H, Columbus, Tex.
Schofield, G. A., P. O. Box 2332, Geop. Div., Houston, Tex.
Scholl, Louis A., Jr., Texas Co., Box 2332, Houston, Tex.
Schoorel, P. M., De Bataafsche Pet. Mij., Tarakan, Borneo, D. E. I.
Schriever, William, 910 Chautauqua Ave., Norman, Okla.
Schumacher, J. P., 830 Shell Bldg., Houston, Tex.
Schwennesen, A. T., 926 Shell Bldg., Houston, Tex.
Seager, O. A., Box 358, Bismarck, N. D.
Seaman, L. O., 3627 Country Club Circle, Ft. Worth, Tex.

Searcy, Frank, Geop. Div., Continental Oil Co., Ponca City, Okla.
Seifert, Wesley H., Box 900, Dallas, Tex.
Seiler, George E., 1702 Tower Petroleum Bldg., Dallas, Tex.
Selby, Ernest R., 218 Columbus Ave., Bakersfield, Calif.
Selig, A. L., Box 3092, Houston, Tex.
*Sessions, Sanson S., Box 2038, Pittsburgh, Pa.
Sexton, Louis P., P. O. Box 591, Tulsa, Okla.
*Seyffert, Willis A., 816 Joplin National Bank Bldg., Joplin, Mo.
Shade, N. R., 3747 Effingham Place, Los Angeles, Calif.
Shafer, Russell E., c/o Sun Oil Co., Beaumont, Tex.
*Shapard, Charles A., 2011 Esperson Bldg., Houston, Tex.
Shappell, M. D., 14731 Valley Heart Drive, Van Nuys, Calif.
Sharpe, Joseph A., Box 591, Tulsa, Okla.
Shaw, Herman, Science Museum, S. Kensington, London, S. W. 7, England
Shepherd, C. Kenneth, R. F. D. 31, Eldon, Mo.
Sherar, E. S., Tidewater Associated Oil Co., Esperson Bldg., Houston, Tex.
Sherar, Stuart, c/o Trinity Petroleum Co., 1706 Esperson Bldg., Houston, Tex.
Shore, H. F., 2011 Esperson Bldg., Houston, Tex.
Shugart, T. R., 1702 Tower Petroleum Bldg., Dallas, Tex.
Shuler, Ellis W., Jr. (Via Overland Route), G. S. I. Geop. Party, California-Arabian Standard Oil Co., Bahrein Island, Persian Gulf, Bagdad-Iraq
*Sibley, W. B., 1117 S. Detroit, Tulsa, Okla.
Siegel, Frank, 2011 Esperson Bldg., Houston, Tex.
Silverman, Daniel, 2608 E. 18th, Tulsa, Okla.
*Sisson, H. H., Palacios, Tex.
Skeels, D. C., c/o Standard Oil Co. of New Jersey, Producing Dept., 30 Rockefeller Plaza, New York, N. Y.
Slichter, Louis B., Room 8-301, M. I. T., Cambridge, Mass.
*Sloane, Medwyn D., Jr., 701 Waugh Drive, Houston, Tex.
Slotnick, M. M., Room 852, Humble Bldg., Houston, Tex.
Small, Walter M., c/o Romano-Americana, Teleajen, Ploesti, Roumania
Smiley, W. G., Jr., Box 2661, Beaumont, Tex.
Smith, Aylwin L., 2011 Esperson Bldg., Houston, Tex.
Smith, C. B., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Smith, Douglas H., Gulf Research and Development Co., P. O. Drawer 2038, Pittsburgh, Pa.
Smith, E. J., Jr., Box 836, Lake Charles, La.
Smith, G. H., Technical Section—Explosives Dept., E. I. du Pont de Nemours & Co., Wilmington, Del.
*Smith, J. Angelo, Humble Oil and Refining Co., Houston, Tex.
*Smith, Louis J., Box 476, Centralia, Ill.
*Smith, Loyd, 1311 Republic Bank Bldg., Dallas, Tex.
Smith, Neal J., Box 1249, Houston, Tex.
Smith, R. Ellis, P. O. Box 1060, Tulare, Calif.
Solari, A. J., Sonora, Calif.
Somers, George B., 4336 Bowser St., Dallas, Tex.
Somers, George W., 816 W. Drew, Houston, Tex.
Sorge, Barthold W., 1065 Kendall Drive, San Gabriel, Calif.
Soske, Joshua L., 199 S. Fair Oaks Ave., Pasadena, Calif.
Souther, J. B., 239 Luther Drive, San Antonio, Tex.
Sparks, Neil R., 1114 S. Urbana St., Tulsa, Okla.
Spencer, Leslie C., 914 Giddens-Lane Bldg., Shreveport, La.
Spencer, M. G., 1311 Republic Bank Bldg., Dallas, Tex.
Spooner, K. K., 1402 Sterling Bldg., Houston, Tex.
Stanton, Austin N., Texas Geophysical Co., 1409 Dallas National Bank Bldg., Dallas, Tex.
Staples, Guy W., P. O. Box 2038, Pittsburgh, Pa.
Statham, Louis, Box 2180, Houston, Tex.
Stearn, Noel H., 2101 Missouri Pacific Bldg., St. Louis, Mo.
Steele, W. E., Jr., 2011 Esperson Bldg., Houston, Tex.

*Steider, J., Reinosa 16, Mexico City, Mex.
*Stephenson, L. B., Box 2061, San Antonio, Tex.
Stick, John C., Jr., 1701 Bushnell Ave., S. Pasadena, Calif.
Stiles, Elisabeth, 2011 Esperson Bldg., Houston, Tex.
*Stone, George B., 2305 Esperson Bldg., Houston, Tex.
Stoneham, S. C., 1311 Republic Bank Bldg., Dallas, Tex.
*Stones, J. Eugene, P. O. Box 96, c/o Superior Oil Co., Bakersfield, Calif.
Storm, Alfred E., Ned. Pacific Pet. Mij., Paleisweg 33, Medan, Sumatra, N. E. I.
Strachan, Clyde G., c/o Gulf Oil Corp., Geol. Dept., Box 661, Tulsa, Okla.
Straley, H. W., III, Box 363, Waco, Tex.
Stratton, Everett F., 3409 Prairie Ave., Mattoon, Ill.
Stubbe, G., American Askania Corp., 826 M. & M. Bldg., Houston, Tex.
Stulken, E. J., 1311 Republic Bank Bldg., Dallas, Tex.
*Sullivant, George A., 1311 Republic Bank Bldg., Dallas, Tex.
Sundt, O. F., 1312 Esperson Bldg., Houston, Tex.
Swan, Bird G., Geop. Div., Continental Oil Co., Ponca City, Okla.
Swartz, Charles A., P. O. Box 2038, Pittsburgh, Pa.
Sweet, Elliott, 206 1924 N. Argyle St., Hollywood, Calif.

*Tabor, E. M., 1702 Tower Petroleum Bldg., Dallas, Tex.
Taylor, Albert, P. O. Box 2040, Tulsa, Okla.
Taylor, John E., Arkansas Natural Gas Corp., Slattery Bldg., Shreveport, La.
Taylor, Josiah, 2513 Gulf Bldg., Houston, Tex.
Taylor, W. Harlan, Petty Geophysical Engineering Corp., Box 2061, San Antonio, Tex.
Teague, N. P., Stanolind Oil and Gas Co., P. O. Box 591, Tulsa, Okla.
Templeton, James C., c/o Geophysical Prospecting Co. Ltd., 9/11, Copthall Ave., London, E. C. 2, England
Terry, Melvin C., Humble Oil and Refg. Co., Houston, Tex.
Texter, John W., Aptdo. 45, c/o Seis. Party #6, Barcelona, Venezuela, S. A.
Thomas, Earl, Box 72, Maypearl, Tex.
*Thomas, George S., Arkansas-Louisiana Gas Co., Shreveport, La.
Thomas, J. W., 825 Esperson Bldg., Houston, Tex.
Thomas, J. W., Jr., c/o Stanolind Oil and Gas Co., Canadian, Tex.
Thompson, Robert R., Humble Oil and Refg. Co., Houston, Tex.
*Thomsen, Erik, 20 Crites Bldg., Bakersfield, Calif.
Thomsen, Harry L., c/o Shell Oil Co., Inc., 1008 W. 6th St., Los Angeles, Calif.
Thornburgh, H. R., Shell Petroleum Corp., 1008 W. 6th St., Los Angeles, Calif.
Thralls, H. M., 709 Kennedy Bldg., Tulsa, Okla.
Tiedemann, Alex, c/o Bat. Petrol. My., Carel v. Bylandtlaan 30, The Hague, Holland
*Tompkins, Frederick A., 77 Lake Crest Road, Rochester, N. Y.
Toomey, Eugene James, 3808 Cedar Springs Road, Dallas, Tex.
Tracy, W. H., 926 W. 1st St., Los Angeles, Calif.
Treybig, B. H., Jr., Texas Co., Box 2332, Houston, Tex.
*Tripp, R. Maurice, c/o Geotechnical Corp., 1702 Tower Petroleum Bldg., Dallas, Tex.
*Tucker, Paul M., c/o H. T. Abercrombie, Barnard, Kan.

Uhrig, L. F., c/o Shell Pet. Corp., Houston, Tex.
*Ulak, Brunislaus S., c/o Mott-Smith Corp., 909 Shell Bldg., Houston, Tex.
Unger, Earle E., Drawer 2038, Pittsburgh, Pa.
Urbom, O. W., 905 Woodrow, Houston, Tex.
*Urick, R. J., Box 2332, Houston, Tex.

Vacquier, Victor, Drawer 2038, Pittsburgh, Pa.
Vallat, E. H., 700 Edison Bldg., 601 W. 5th St., Los Angeles, Calif.
*Van Berg, L. L., Box 2061, San Antonio, Tex.
Van Beveren, O. F., 4361 Colfax Ave., N. Hollywood, Calif.
Van Cleave, R. F., c/o National Geophysical Co., Tower Pet. Bldg., Dallas, Tex.
Van Croy, Stefan, c/o Barnsdall Oil Co., 2212 Esperson Bldg., Houston, Tex.
van Melle, F. A., 3515 Robinhood, Houston, Tex.

Van Orstrand, C. E., U. S. G. S., Interior Dept. Bldg., 3906 Morrison St., N. W., Washington, D. C.
Van Weelden, A., c/o Shell Oil Co., Inc., Shell Bldg., Houston, Tex.
*Vercesi, Daniel Rey, 2563, Avenida General San Martin, Montevideo, Uruguay, S. A.
Vernon, Jess, Box 2040, Tulsa, Okla.
Verheis, Byron, Continental Oil Co., Ponca City, Okla.

Wachter, C. A., 1255 E. Green St., Pasadena, Calif.
*Wagner, Roland B., address unknown
Wagoner, George E., Box 801, Tulsa, Okla.
Walczak, Michael J., National Geophysical Co., 1002 Tower Petroleum Bldg., Dallas, Tex.
Walford, R. M., Jr., 420 Stephenson St., Shreveport, La.
*Walker, Weldon F., c/o Burmah Oil Co. Ltd., Digboi, Assam, India
Wallace, C. R., c/o Mr. L. A. Scholl, Jr., P. O. Box 2332, Houston, Tex.
Walling, Dean, Western Geophysical Co., 711 Edison Bldg., Los Angeles, Calif.
Wallis, W. E. Standard Oil Co. of Egypt, S. A., 22 Shari Kasr el Nil, Cairo, Egypt
Walsh, T. N., 1311 Republic Bank Bldg., Dallas, Tex.
*Walton, George G., Magyar Amerikai Olajipari Rt., Ferenc Josef ter 5, Budapest V, Hungary
Wantland, Dart, Colorado School of Mines, Golden, Colo.
*Ward, Dwight E., Carter Oil Co., Box C, Phillipsburg, Kansas
Waring, W. W., International Pet. Co., Casilla 803, Guayaquil, Ecuador, S. A.
Warren, Paul R., c/o Continental Oil Co., Ponca City, Okla.;
Warrick, Thomas R., c/o Standard Oil Co. of Venezuela, Caripito, Venezuela, S. A.
Washburn, H. W., 1255 E. Green St., Pasadena, Calif.
Waterfall, Louis N., 1105 Hillcroft Road, Glendale, Calif.
Waters, Kenneth H., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
Watson, George R., Box 2038, Pittsburgh, Pa.
Watson, R. A., National Geophysical Co., Box 486, Alexandria, La.
Watson, Robert J., Room 2154, 30 Rockefeller Plaza, New York, N. Y.
Watt, J. S., 261 Humble Bldg., Houston, Tex.
Weatherby, B. B., Box 2040, Tulsa, Okla.
Weatherby, S. P., 709 Kennedy Bldg., Seismograph Service Corp., Tulsa, Okla.
Weaver, Paul, Drawer 2100, Houston, Tex.
*Weber, David M., 226 East End Ave., Pittsburgh, Pa.
Weinzierl, John F., Lauratal, Riverside, Walker County, Tex.
Weisbrich, R. A., P. O. Box 2061, San Antonio, Tex.
Weiss, Oscar, 902 S. A. Mutual Bldg., Commissioner St., Johannesburg, Union of South Africa
*Wells, Robert J., National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
Wells, William M., c/o Geol. Dept., Arkansas Fuel Oil Co., Shreveport, La.
Wert, Carl M., P. O. Drawer 2038, Pittsburgh, Pa.
*Wessler, George H., Jr., c/o R. L. Suggs, Geol. Dept., Humble Party, N. K. P. M. Soengei Gerong, Palembang, Sumatra, N. E. I.
West, S. Stewart, Geop. Lab., Stanolind Oil and Gas Co., Box 591, Tulsa, Okla.
Westby, G. H., Seismograph Service Corp., 711 Kennedy Bldg., Tulsa, Okla.
Wetzel, W. W., Dept. of Physics, U. of Minnesota, Minneapolis, Minn.
*Wheaton, G. S., 225 Bush St., San Francisco, Calif.
White, Gifford E., 273 Beacon St., Boston, Mass.
*White, K. D., Standard Oil Co., of Egypt, 22, Sharia Kasr el Nil, Cairo, Egypt
White, Rankin J., 611 Esperson Bldg., c/o McCollum Exploration Co., Houston, Tex.
White, Rex H., c/o Magnolia Geol. Lab., 721 Browder St., Dallas, Tex.
*White, S. A., 2011 Esperson Bldg., Houston, Tex.
*White, W. T., Off. 10-213, M. I. T., Cambridge, Mass.
Whitehead, L. E., Continental Oil Co., Ponca City, Okla.
Whitney, Paul A., 2513–14 Gulf Bldg., Houston, Tex.
Whiton, Herman F., 33 Rector St., New York, N. Y.
Whitsitt, C. D., Box 2061, San Antonio, Tex.

Widess, M. B., 1541 Rose Villa St., Pasadena, Calif.
Wilcox, Stanley W., Box 405, Jackson, Miss.
*Wiley, W. B., P. O. Box 114, Watonga, Okla.
Williams, Charles C., c/o National Geophysical Co., Tower Petroleum Bldg., Dallas, Tex.
*Williams, C. E., c/o Aizar Chemas, Tex. Pet. Co., La Dorada, Colombia, S. A.
*Williams, E. D., Universal Exploration Co., Shell Bldg., Houston, Tex.
Williams, Floyd J., 1311 Republic Bank Bldg., Dallas, Tex.
Williams, P. S., c/o Carter Oil Co., Tulsa, Okla.
Williams, Richard, 1001 Tower Petroleum Bldg., Dallas, Tex.
*Williams, W. J., Gulf Research and Development Corp., Pittsburgh, Pa.
Willis, Floyd, Jr., General Geophysical Co., 2513–14 Gulf Bldg., Houston, Tex.
Williston, Samuel H., 909 Studio Bldg., Portland, Ore.
Wilson, Clyde H., P. O. Box 4241, Village Station, Los Angeles, Calif.
Wilson, Gardner P., 150 S. Madison Ave., Pasadena, Calif.
Wilson, H. A., 5510 Chenevert, Houston, Tex.
Wilson, John H,, 2306 Park Place, Ft. Worth, Tex.
Wilson, Richard M., Box 1129, Shreveport, La.
Winkler, B. O., c/o N. K. P. M., Soengei Gerong, Palembang, Sumatra, N. E. I
*Winn, Clayton N., Box 2040, Tulsa, Okla.
Winnek, J. R. Box 2040, Tulsa, Okla.
Winter, A. B., 2 NW 10th St., Oklahoma City, Okla.
Winter, Niles B., P. O. Box 871, Midland, Tex.
Wise, L. H., c/o National Geophysical Co., Dallas, Tex.
Witt, M. K., Jr., 256 Humble Bldg., Houston, Tex.
Wolf, Alexander, Texas Co., Box 2332, Houston, Tex.
Wolters, Earl M., 3332 Columbine, Denver, Colo.
Wood, J. E. R., c/o Geop. Dept., Anglo-Iranian Oil Co., Ltd., Britannic House, Finsbury Circus, London E. C. 2, England
Woods, J. P., 406 Sul Ross, Houston, Tex.
Woods, R. E., 1199 Calaveras St., Altadena, Calif.
*Woodward, R. V., 232 N. Sycamore, Centralia, Ill.
Woodward, Richard H., P. O. Box 131, Jackson, Miss.
Woolley, William C., 721 Browder St., Dallas, Tex.
Wyckoff, Ralph D., P. O. Box 2038, Pittsburgh, Pa.

*Yeates, F. L., 2011 Esperson Bldg., Houston, Tex.

*Zavoico, Basil B., Chase National Bank, 18 Pine St., New York, N. Y.
Zazvorka, Jerry, Jr., 254-C Humble Bldg., Houston, Tex.
Zeigler, B. F., 1517 Bella Vista Drive, Dallas, Tex.
Zenor, H. M., 275 Humble Bldg., Houston, Tex.
Zimerman, Sam, Box 387, Philip, S. D.
Zimmerman, C. C., Texas Co., Box 2332, Houston, Tex.
Zirbel, N. N., 2011 Esperson Bldg., Houston, Tex.

MEMBERSHIP LIST BY GEOGRAPHICAL LOCATIONS

UNITED STATES

ALABAMA

Mobile
Meitzen, J. B.

Russellville
Head, E. I.
Kilborn, J. M.

CALIFORNIA

Altadena
Woods, R. E.

Arcadia
Hoffman, John C.

Bakersfield
Clement, Paul F.
Dana, Drexler
Denning, Wayne H.
Ferber, Herbert J.
Fleishman, Sam
Gaby, Phil P.
Griffin, I. M., Jr.
Haskell, Norman A.
Ittner, Frank
Le Conte, Joseph
Mathews, John W.
Pezdek, Victor J.
Reel, C. E.
Saunders, L. W.
Selby, Ernest R.
Stones, J. Eugene
Thomsen, Erik

Beverly Hills
Herald, Frank B.
Loy, Milton E.

Burbank
Gayman, W. H.

Fresno
Hedstrom, A. A.
Heggblom, J. C.

Glendale
Pratley, H. Hart
Waterfall, Louis N.

Hanford
Ellsworth, T. P.
Lash, Charles C.

Hollywood
Sweet, Elliott

La Canada
Moran, R. B., Jr.

Long Beach
Henquet, R.
Hodgson, John H.
Reed, Charles F., Jr.

Los Angeles
Acker, Ralph F.
Batchelder, Dean E.
Benke, M. L.
Boccalery, Michael A.
Bradbury, F. D.
Clark, R. W.
Desmond, Jack M.
Donnally, Chester J.
English, Walter A.
Gilmore, Homer
Jurin, Boris M.
Mason, Jack
Maxwell, Joseph M.
McCloskey, Downs
McGrady, Dupree
Norelius, Russell G.
North, Willard
Price, Wiley R., Jr.
Rieber, Frank
Romberg, Frederick E.
Salvatori, Henry
Shade, N. R.
Thomsen, Harry L.
Thornburgh, H. R.
Tracy, W. H.
Vallat, E. H.
Walling, Dean
Wilson, Clyde H.

Martinez
Baird, Walter D.

Monterey Park
Rock, Sibyl M.

North Hollywood
Van Beveren, O. F.

Oakland
Hoylman, H. Wayne

Pasadena
Benioff, Hugo
Christie, Norman J.
Gabriel, V. G.
Gutenberg, Beno
Harding, Maynard W.
Mansfield, Robert H.
Morgan, Charles Gill
Morris, Lawrence K.
Peterson, Raymond A.
Rupnik, J. Joseph
Soske, Joshua L.
Wachter, C. A.
Washburn, H. W.
Widess, M. B.
Wilson, Gardner P.

Riverside
Hull, J. W.

San Bernardino
Eichelberger, A. M., Jr.

San Diego
Long, John V.

San Francisco
Hillis, Donuil
Wheaton, G. S.

San Gabriel
Sorge, Barthold W.

Santa Monica
Johnson, Curtis H.

Sierra Madre
Hoover, Herbert, Jr.

Sonora
Solari, A. J.

South Pasadena
Lohman, R. W.
McKanna, Edwin A.
Nomann, Arthur B.
Stick, John C., Jr.

Tulare
Hall, Hubert N.
Northcutt, W. C.
Smith, R. Ellis

Van Nuys
Shappell, M. D.

Whittier
Lynton, Edward D.

COLORADO

Denver
Boos C. Maynard
Cox, Charles B.
Hawkins, J. E.
Johnson, L. H.
Levings, W. S.
Manning, A. B.
Wolters, Earl M.

Fort Morgan
Rickel, Wesley K.

Golden
Dissler, Ernest
Heiland, C. E.
Wantland, Dart

Greeley
Bliss, Robert, Jr.

DELAWARE

Wilmington
Budd, Montgomery R.
Smith, G. H.

DISTRICT OF COLUMBIA

Washington
Van Orstrand, C. E.

FLORIDA

Coral Gables
Blanchard, William G.

ILLINOIS

Centralia
Ellsworth, Elmer W.
Koenig, Palmer E.
Smith, Louis J.
Woodward, R. V.

Chicago
Bench, B. M.
Cram, Ira H.
Parkhurst, George L.
Riley, N. Allen

Fairfield
Davies, Nathan C.

Glencoe
McAllen, W. J.

Marshall
Konkel, Philip M.

Mattoon
Stratton, Everett F.

INDIANA

Evansville
Horton, H. M.

IOWA

Ames
Johnston, T. F.

KANSAS

Barnard
Tucker, Paul M.

Dodge City
Dana, R. H.

Great Bend
Elam, Daniel F.

Lawrence
Jakosky, J. J.

Saint John
Brewer, Ralph R., Jr.

LOUISIANA

Alexandria
Bastian, Joseph W.
Watson, R. A.

Baton Rouge
Schneider, John E.

Houma
Foster, Edward S., Jr.
Hamilton, W. B.

Jena
Goebel, Lawrence A.

Lake Charles
Smith, E. J., Jr.

New Orleans
Gay, Andrew H.

Shreveport
Barret, William M.
Caster, E. L.
Cooke, John G., Jr.
Crain, Ashton
Freeman, L. I.
Horn, J. W.
Howard, G. C.
Ivy, John S.
Lea, W. T.
Lowe, C. R.
McLaren, R. L.
Spencer, Leslie C.
Taylor, John E.
Thomas, George S.
Walford, R. M., Jr.
Wells, William M.
Wilson, Richard M.

Sulphur
Moore, James A.

MARYLAND

Cumberland
Malamphy, Mark C.

MASSACHUSETTS

Boston
White, Gifford E.

Cambridge
Beers, Roland F.
Slichter, Louis B.
White, W. T.

Woods Hole
Ewing, Maurice

MICHIGAN

Detroit
Bodor, Leslie

MINNESOTA

Minneapolis
Wetzel, W. W.

MISSISSIPPI

Aberdeen
Lemke, Ernest W.

Columbia
Reed, Paul C.

Columbus
Agee, F. H.
Chandler, Lyman, Jr.
Schoellhorn, Henry, III

Jackson
Gaby, Edwin D.
Wilcox, Stanley W.
Woodward, Richard H.

Meridian
Cady, Francis H.
Fischer, L. F.

Philadelphia
Ward, Dwight E.

Ripley
Clayton, Neal

MISSOURI

Eldon
Shepherd, C. Kenneth

Joplin
Latimer, M. W.
Seyffert, Willis A.

Saint Louis
Macelwane, James B., S.J.
Stearn, Noel H.

NEW HAMPSHIRE

Hanover
Cobb, Howard L.

NEW JERSEY

Gibbstown
Burrows, L. A.

NEW MEXICO

Carlsbad
Kearns, B. E.

NEW YORK

Albany
Myers, Clay K.

Larchmont
Paslay, L. C.

New York
Dix, C. H.
Douglas, Norvel
Gibbon, H. A.
Hardy, Willis W.
Hubbard, Bela
Moorman, H. R.
Pratt, W. E.
Skeels, D. C.
Watson, Robert J.
Whiton, Herman F.
Zavoico, Basil B.

Rochester
Jameson, M. H.
Tompkins, Frederick A.

NORTH DAKOTA

Bismark
Seager, O. A.

Linton
Barger, Thomas C.

OKLAHOMA

Ardmore
Imle, Harry R.

Bartlesville
Beck, August F.
Bradley, R. M.
Courtier, William H.
Dietert, Arthur E.
Doan, Richard L.
Ericson, Harry B.
Hintze, A. J.
Kidd, Robert L.
Miller, Vincent

Blair
Roberts, Louin W.

Norman
Schriever, William

Oklahoma City
Schaeffer, Hugh C.
Winter, A. B.

Ponca City
Athy, L. F.
Beeth, Donald
Crawford, John M.
Erickson, Anton
Haber, A. F.
Handley, E. J.
Hughes, Roland F.
Jordan, C. K.
Moody, Herbert H.
Mount, E. L.
Mullinax, Jack D.
Peterson, V. A.
Prescott, H. R.
Searcy, Frank
Swan, Bird G.
Vorheis, Byron
Warren, Paul R.
Whitehead, L. E.

Shawnee
Perry, W. B.

Tulsa
Anderson, O. W.
Barthelmes, Albert J.
Becker, H. C.
Bible, John L.
Bills, Robert N.
Bishop, F. L.
Blight, Richard E.
Borman, F. W.
Born, Milton C.
Born, W. T.
Bryan, A. B.
Bullock, Robert Lee
Burton, R. H.
Clark, R. C.
Cloud, Raymond T.
Coffin, R. Clare
Dahlberg, R. S., Jr.
Davenport, Robert
Day, Charles E.
Dyk, Karl
Eisler, Joseph D.
Emrick, D. G.
England, C. M.
Evans, Eugene P.
Faust, L. Y.
Ferguson, John L.
Flournoy, Murray B.
Fraker, C. L.
Gemmer, R. W.
Gilliam, J. T.
Gilliland, J. R.
Gilmour, Andrew
Gould, Martin J.
Green, W. G.
Harding, R. L.
Harlton, Bruce H.
Hawley, Paul F.
Hoffman, Malvin G.
Hopkins, James S.
Houghton, H. M.
Hurry, Clara N.
Innes, Arland I.
Kendall, G. D.
Kendall, James M.
Kendall, W. B.
Lawrence, K. M.
Lester, O. C., Jr.
Long, Clarence J.
Lynn, Ralph D.
Manhart, T. A.
Marsh, Samuel R.
Martin, Dick
McGinity, J. V.
McNatt, E. M.
Nash, C. C., Jr.
Owen, J. E.
Peters, Leo J.
Ricker, Norman H.
Riess, Malcolm
Ross, Charles M.
Rutledge, Richard B.
Sargent, R. L.
Sexton, Louis P.
Sharpe, Joseph A.
Sibley, W. B.
Silverman, Daniel
Sparks, Neil R.
Strachan, Clyde G.
Taylor, Albert
Teague, N. P.
Thralls, H. M.
Vernon, Jess
Wagoner, George E.
Weatherby, B. B.
Weatherby, S. P.
West, S. Stewart
Westby, G. H.
Williams, P. S.
Winn, Clayton N.
Winnek, J. R.

Warren
Roark, James J.

Watonga
Wiley, W. B.

OREGON

Portland
Williston, Samuel H.

PENNSYLVANIA

Philadelphia
Bazzoni, Charles B.

Pittsburgh
Affleck, James
Agocs, William B.
Allon, Michael
Backman, John E.
Bailey, Lothrop H.
Boots, Paul H.
Bradford, Donald C.
Bryan, Carl L.
Butler, Mark D.
Caldwell, C. L.
Cerveny, Philip F.
Cook, D. E.
Copeland, R. J.
DeGood, R. G.
Diveley, Paul R.
Dobrin, Milton B.
Dombart, William F.
Dresbach, C. H.
Dreyfus, Robert M.
Eckhardt, E. A.
Elkins, Thomas A.
Evinger, H. H.
Ferrick, James H.
Gardner, Louis W.
Gealy, Wendell B.
Gemmell, Howard F.
Gunn, J. E.
Hammer, Sigmund I.
Hastings, W. K.
Hollobaugh, Robert C.
Jones, Ralph E.
Kerbow, R. B.

Lee, Walter B., Jr.
Lehman, Frank F.
McCracken, Guy I.
McGee, John E.
Meszaros, W. A.
Meyer, Edgar J.
Mortlock, Frank O.
Muffly, Gary
Muskat, Morris
Nettleton, L. L.
Palmer, E. M.
Perkins, B., Jr.
Reiser, Robert G.
Ritzmann, O. F.
Robinson, W. Bernard
Ross, R. B.
Sessions, Sanson S.
Smith, Douglas H.
Staples, Guy W.
Swartz, Charles A.
Unger, Earle E.
Vacquier, Victor
Watson, George R.
Weber, David M.
Wert, Carl M.
Williams, W. J.
Wyckoff, R. D.

State College
Pirson, Sylvain J.

Trafford
Carson, J. P.

Verona
Rusler, George W.

SOUTH DAKOTA

Philip
Zimerman, Sam

TEXAS

Austin
Brown, Leon D., Jr.
Davenport, George
Gallie, J. F.
Harris, Stevens T., Jr.
Konz, Leo W.

Beaumont
Anderson, John F.
Blocher, Charles L. M.
Ellis, L. G.
Hollingsworth, W. E.
Nahas, J. N.
Prade, Nat H.
Rose, H. W.
Shafer, Russell E.
Smiley, W. G., Jr.

Birthright
Hargis, A. V.

Canadian
Thomas, J. W., Jr.

Corpus Christi
Howerton, Bert P.
Pranglin, John A.

Dallas
Adams, Hal R.
Albright, E. G.
Augustat, George
Batson, James Burton
Berger, Joe C.
Brown, H. Hallock
Browning, K. A.
Burdine, N. T.
Burg, Kenneth E.
Carter, Ray K.
Charske, C. J., Jr.
Clark, Charles Lindsey
Collingwood, Douglas M.
Cooper, Jack R.
Cortes, Henry C.
Coursey, Walter D.
Cox, Harris
Dahm, C. G.
De Golyer, E. L.
Dexter, Laurence N.
Dobyns, D. R.
Doering, John
Doss, C. L.
Dunlap, Robert C., Jr.
Elms, R. G.
Fain, Edgar A.
Farren, Paul
Farris, E. A., Jr.
Fetzer, E. L.
Fisher, Barney
Fisher, E. W.
Gillin, John A.
Green, Cecil H.
Harkey, W. J.
Harris, B. A.
Heard, Burton E.
Hedeman, W. R., Jr.
Henderson, Paul V.
Hieatt, Herbert F.
Hogg, W. B.
Honnell, P. M.
Hurt, W. B.
Jackson, Robert W.
Jett, J. E.
Jones, M. P.
Jonsson, J. E.
Karcher, J. C.
Kearby, J. G.
Kennedy, Frank H., Jr.
Kiesler, Ernest A.
Lawhorn, O. T.
Lester, John A.
Lewis, Karl E.
Lukens, John P.
MacNaughton, Lewis W.
Markwardt, E. W.
McBurney, Charles G.
McDermott, Eugene
McGhee, George C.
McLemore, Ethel Ward
Melton, Ben S.
Menefee, James C.
Minton, J. P.
Moon, Jake
Moore, Charles M.
Morrow, Dallas C.
Myers, John R.
Nash, Paul E.
Newton, W. W.
Pernell, J. H.
Perryman, J. D.
Pittman, C. V. A.
Poindexter, Louis
Pollard, J. C.
Pollei, Donald W.
Pratt, R. B.
Ransone, W. R.
Reagor, Edward C.
Renner, Darwin S.
Rice, E. R., Jr.
Rollins, J. Frank
Schley, Woodruff H.
Seifert, Wesley H.
Seiler, George E.
Shugart, T. R.
Smith, C. B.
Smith, Loyd
Somers, George B.
Spencer, M. G.
Stanton, Austin N.
Stoneham, S. C.
Stulken, E. J.
Sullivant, George A.
Tabor, E. M.
Toomey, Eugene James
Tripp, R. Maurice
Van Cleave, R. F.
Walczak, Michael J.
Walsh, T. N.
Waters, Kenneth H.
Wells, Robert J.
White, Rex H.
Williams, Charles C.
Williams, Floyd J.
Williams, Richard
Wise, L. H.
Woolley, William C.
Zeigler, B. F.

Decatur
Johnson, E. W.

Edna
Ervin, Lynn

Fort Sam Houston
Faris, J. R., Jr.

Fort Worth
Harris, Sidon
Hightower, C. H.
Lovejoy, J. B.
Morris, James L.
Paddison, Louis J.
Sandidge, Irl
Seaman, L. O.
Wilson, John H.

Goliad
Pellillo, M. J.

Houston
Adler, Joseph L.
Antes, Leland L.
Arthur, Marion A.
Augenthaler, R. L.
Back, Denys H.
Bader, Glenn E.
Bailey, George F.
Baker, Malcolm C.
Banta, H. E.
Barling, Robert
Barnette, L. Atmar M.
Bennett, Roy F.
Bertram, A. C.
Bilinsky, Solomon
Black, J. P.
Blau, L. W.
Bolinger, John W.
Boucher, F. G.
Bowsky, Merle C.
Brenner, Morris
Brooks, J. A., Jr.
Brooks, O. D.
Broussard, D. F.
Brown, Hart
Brown, Paul B.
Burnett, Arthur C.
Burney, James H.
Busch, H. W.
Butler, W. W.
Byers, J. W.
Campbell, F. F.
Carlson, Joe E.
Carlton, Dave P.
Carr, G. W.
Cash, Harvey, Jr.
Child, V. E.
Clifford, O. C., Jr.
Cowles, Laurence G.
Crandall, K. H.
Crary, Albert P.
Cross, J. W.
Crowell, J. H.
Culbertson, J. A.
Dacus, A. C.
Davis, Donald M.
Deussen, Alexander
Dunlap, A. D.
Durham, Charles A.
Durrett, H. D.
Duty, Robert S., Jr.
Eby, A. N.
Eby, J. Brian
Epperson, R. S.
Evjen, H. M.
Falkenhagen, H. M.
Fecht, Arthur J.
Ferguson, J. G.
Ferguson, W. S.
Ferris, Craig
Flude, J. W.
Fohs, F. Julius
Freel, J. F.
Frosch, Alex
Gahagan, Donald I.
Gardner, Derry H.
Garrett, George A.
Garrett, L. P.
Garrett, William M.
Gerlough, Daniel L.
Gibson, M. O.
Golden, John M.
Goldstone, Frank
Gomez, J. S.
Goss, Henry V.
Grizzell, Edward I.
Guseman, L. F.
Hafner, W.
Hale, Donald H.
Halliday, O. T.
Hamic, Claude P.
Harkins, Curtis P.
Harkins, T. I.
Harrington, G. H.
Hatch, J. D.
Haynes, C. J.
Henderson, Homer I.
Herzenberg, A. J.
Heyer, George S.
Hibbler, Alfred J.
Hibbler, M. E.
Hillyer, Ray H.
Hoard, J. O.
Holland, Aaron E.
Holland, Sam B.
Hoover, J. W.
Horton, Claude Wendell
Horvitz, Leo
Houston, Charles E.
Howell, Lynn G.
Hughes, Darrell S.
Hunsaker, Neville C.
Hunzicker, A. A.
Irby, W. L.
Jackson, G. L.
Jackson, Ralph S.
Jaques, Alvin T.
Jerome, J. Glen
Judson, Sidney A.
Kannenstine, Fabian M.
Kerns, A. D.
Klipsch, Paul W.
Kretz, Robert L.
Ladner, A. L.
Lake, J. L.
Lamb, George B.
Langley, R. M.
LaRue, James E.
LaRue, Wilton W.
Leonardon, E. G.
Lewis, William Bradley
Lipson, Edward
Lohse, John M.
Lyons, Richard T.
MacMahon, A. M.
Manes, O. B.
Mannes, W. H.
Manning, Earl L.
Manning, W. G.
Marr, John D.
Marti, J. E.
Mason, C. C.
Maxwell, E.
McCaleb, M. M.
McCartney, Reed L.
McCollum, Burton
McCollum, Elton V.
McLarry, Weldon G.
Melton, E. Roane
Merion, G. Ralph
Merritt, H. W.
Metcalf, D. F., Jr.
Miller, Arthur B.
Miller, R. D.
Millet, M. J.
Mitchell, George D., Jr.
Montgomery, George P.
Moore, Arthur A., Jr.
Moore, Homer C.
Morgan, Wesley H.
Morris, Euclid
Mott-Smith, L. M.
Mott-Smith, M.
Mounce, W. D.
Muzzey, David S., Jr.
Neff, W. D.
Neumann, G.
Neuman, L. J.
Newby, C. J.
Noser, W. P.
O'Brien, Decatur
Osterhoudt, W. J.
Palmer, John E.
Palmer, R. L.

Parker, L. A.
Patrick, H. G.
Peacock, H. B.
Pope, Turner T.
Ransone, Keating
Ray, R. H.
Reynolds, F. F.
Rolshausen, F. W.
Rosaire, Carol G.
Rosaire, E. E.
Rulfs, G. W., Jr.
Rust, W. M., Jr.
Rutherford, Homer M.
Saibara, Robert
Sanders, C. W.
Saville, W. G.
Schafer, Sidney
Scharf, David
Schiflett, H. L.
Schmidt, Henry
Schmuck, R. H.
Schoefield, G. A.
Scholl, Louis A., Jr.
Schumacher, J. P.
Schwennesen, A. T.
Selig, A. L.
Shapard, Charles A.
Sherar, E. S.
Sherar, Stuart
Shore, H. F.
Siegel, Frank
Sloane, Medwyn D.
Slotnick, M. M.
Smith, Aylwin L.
Smith, J. Angelo
Smith, Neal J.
Somers, George W.
Spooner, K. K.
Statham, Louis
Steele, W. E., Jr.
Stiles, Elisabeth
Stone, George B.
Stubbe, G.
Sundt, O. F.
Taylor, Josiah
Terry, Melvin C.
Thomas, J. W.
Thompson, Robert R.
Treybig, B. H., Jr.
Uhrig, L. F.
Ulak, Brunislaus S.
Urbom, O. W.
Urick, R. J.
Van Croy, Stefan
van Melle, F. A.
Van Weelden, A.
Wallace, C. R.
Watt, J. S.
Weaver, Paul
White, Rankin J.
White, S. A.
Whitney, Paul A.
Williams, E. D.
Willis, Floyd, Jr.
Wilson, H. A.
Witt, M. K., Jr.
Wolf, Alexander
Woods, J. P.
Yeates, F. L.
Zazvorka, Jerry, Jr.
Zenor, H. M.
Zimmerman, C. C.
Zirbel, N. N.

Kingsville
Martin, Sidney A., Jr.

Lubbock
Klaus, H.

Maypearl
Thomas, Earl

McAllen
Brown, C. Bradner

Midland
McKay, A. E.
Winter, Niles B.

Palacios
Sisson, H. H.

Palestine
Ervin, C. H.
Kerns, G. P.
MacAllister, C. T.

Pecos
Ruhlen, W. W.

Riverside
Weinzierl, John F.

Rosenberg
Hotard, A. A.

San Antonio
Allen, Thomas L.
Bazhaw, W. O.
Bevier, George M.
Crawford, Paul D.
DeLoach, Edward L.
Gill, W. D.
Imle, John F.
Mariner, R. E., Jr.
Mayfield, W. I.
McAlister, C. H.
Moore, Marion J.
Moore, W. Lee, Jr.
Navarte, P. E.
Petty, Dabney E.
Petty, O. S.
Rodgers, P. A.
Sawtelle, D. M.
Souther, J. B.
Stephenson, L. B.
Taylor, W. Harlan
Van Berg, L. L.
Weisbrich, R. A.
Whitsitt, C. D.

Stratford
Buffum, C. Emery

Waco
Straley, H. W., III

Wharton
Kaiser, George B.

Wichita Falls
Schmidt, Karl H., Jr.

Woodsboro
McMullin, E. F.

WYOMING

Rawlins
Johnston, Frank M.

FOREIGN

ARGENTINA

Buenos Aires
Leedy, F. B.
Ramaccioni, D.
Rey, Pedro
Rozlosnik, Andres

AUSTRALIA

Melbourne
Milstein, Mark N

BORNEO

Balik Papan
De Blank, B.
Maliphant, H. C.

Sangasanga
Postma, G. W.

Tarakan
Schoorel, P. M.

BRAZIL

Rio de Janeiro
Amaral, I. C. do
Oddone, Decio Saverio

BURMA

Rangoon
Jackson, J. B.
Richards, T. C.
Roberts, Homer E.

CANADA

Calgary
Paterson, R. G.

Toronto
Berwick, J. D.
Kelly, Sherwin F.
Lundberg, Hans

Winnipeg
Duncan, J. E.

COLOMBIA

Barranca Bermeja
Curnutt, F. E.

Barranquilla
McCready, H. J.

Bogota
Bonillas, Ygnacio
Etherington, Thomas J.
Legge, J. A., Jr.
Markstein, Georg
Samuels, G. H., Jr.
Sawyer, J. H.

Cucuta
Barksdale, G. L.

El Centro
Acheson, C. H.
Minturn, L. W.

La Dorada
Williams, C. E.

Pasto
Morrison, M. S.

Puerto Wilches
Judson, J. F.

CUBA

Los Palacios
Jasinski, Edward J.

Pinar del Rio
Hubner, B. G., Jr.

DOMINICAN REPUBLIC

Ciudad Trujillo
Arick, Millard B.

ECUADOR

Guayaquil
Loring, Ralph C.
Meador, Bernal M.
Waring, W. W.

EGYPT

Cairo
Dickey, Calvin A. L.
Gallaway, Roy Lee
Haight, H. W.
Wallis, W. E.
White, K. D.

ENGLAND

Cheshire
Germain-Jones, D. T.

Hertford
Brown, C. Barrington

London
Davies, Richard
Shaw, Herman
Templeton, James C.
Wood, J. E. R.

Northampton
Gossage, R. J.

Surrey
Jones, John H.

FRANCE

Paris
Schlumberger, Marcel

GERMANY

Berlin
Bentz, Alfred

Breslau
Mintrop, L.

Hamburg
Kauenhowen, Walter

Hanover
Schleusener, Ludwig
Brinckmeier, Georg

Steinau I Odenwald
Koenigsberger, J. G.

HOLLAND

The Hague
Craig, Robert L.
Tiedemann, Alex

HUNGARY

Budapest
Walton, George G.

INDIA

Digboi
Walker, Weldon F.

Karachi
Brown, Donald R.
de Bruyn, J. W.

IRAN

Masjid-I-Suleiman
Barnett, G. W. T.

ITALY

Milan
Emanuel, Vincent

MEXICO

Mexico City
Alvarez, Manuel, Jr.
Malcher, Kurt
Rojas, A. Garcia
Steider, J.

NEW ZEALAND

New Plymouth
Kennedy, Kenneth K.

PERSIAN GULF

Bahrein Island
Kerr, Richard C.
Mann, Neil W.
Olson, O. C.
Shuler, Ellis W., Jr.

PERU

Negritos
Alber, John L.

PHILIPPINE ISLANDS

Manila
Moore, Horace S.
Ross, J. D.

ROUMANIA

Ploesti
Alexander, Warren A.
Constantinescu, M.
Small, Walter M.

RUSSIA

Lwow
Mitera, Z. A.

SARAWAK

Miri
de Pijper, T.

SUMATRA

Medan
Blevins, David C.
Coit, R. B.
Davis, E. O.
Lovinggood, Toby
Nichols, E. Turnley
Storm, Alfred E.

Soengei Gerong
Dahlberg, Jack K.
Egan, Daniel G.
Roberts, Francis A.
Romberg, M.
Wessler, George H., Jr.
Winkler, B. O.

SWITZERLAND

Zurich
Fisch, W.

UNION OF SOUTH AFRICA

Johannesburg
Krahmann, Rudolf
Weiss, Oscar

URUGUAY

Montevideo
Vercesi, Daniel Rey

VENEZUELA

Barcelona
O'Donnell, T. J.
Texter, John W.

Caracas
Brotherhood, G. Roy
Franks, W. E.
Gerdes, C. H.
Higgins, G. E.
Kamen-Kaye, M.
Kaufmann, G. F.
Kimble, Henry R.
Lee, B. D.
Merritt, W. C.
Mix, Adrian E.
Perkinson, Floyd

Caripito
Browning, Paul
Neidert, John H.
Warrick, Thomas R.

Ciudad Bolivar
Odenweller, Keith H.

Maracaibo
Ramsden, C. H.

INDEX TO VOLUME V OF *GEOPHYSICS* FOR 1940

	No.	Page
Additional Evidence on the Relation of Temperature to Structure in the Salt Creek Oil Field, Natrona County, Wyoming. C. E. Van Orstrand	1	47
Age of the Earth, Geothermal Methods of Estimating the. C. E. Van Orstrand	1	57
Ballot—1940 Election	1	111
Beers, Roland F. Velocity Stratification as an Aid to Correlation	1	15
Biot, Maurice A., and Karman, Theodore v. Mathematical Methods in Engineering. Review by Morris Muskat	2	196
Blondeau, Ernest Eugene—Memorial by B. B. Weatherby	1	102
Brief History of the Gravity Method of Prospecting for Oil, A. E. A. Eckhardt	3	231
By-Laws, Constitution and, of the Society of Exploration Geophysicists	4	413
———, Amendments to the	4	420
Change of Reflection Amplitude and Character with Geophone Depth. H. M. Houghton	2	169
Characteristics, Shot Hole, in Reflection Seismology. H. J. McCready	4	373
Chemical Exploration, Some Neglected Aspects of. R. Thomas Sanderson	3	284
Coefficients, Reflection and Transmission, for Plane Waves in Elastic Media. M. Muskat and M. W. Meres	2	115
Communications	4	402
———, Discussions and. Note on the Change in Frequency of the Reflection from Basement as this Reflecting Horizon Increases. Sidon Harris and N. A. Haskell	2	194
Computation and Mapping of Seismic Reflection Data, The. M. B. Widess and N. A. Haskell	2	156
Computing Magnetic and Gravitational Anomalies, An Experimental Device for. J. W. Fisher	1	22
Constitution and By-Laws of the Society of Exploration Geophysicists	4	413
———, Amendments to the	4	420
Core Orientation, Magnetic—The Mechanics of the Upside Down Core. Edward D. Lynton	4	393
Correlation, Velocity Stratification as an Aid to. Roland F. Beers	1	15
Curves, Formulas and, for the Interpretation of Certain Two-Dimensional Magnetic and Gravitational Anomalies. Harold H. Pentz	3	295
———, Three-Layer Resistivity, for the Eltran Electrode Configuration. S. S. West	1	43
Department of Geophysics, Geophysical Education in a. James B. Macelwane, S.J.	1	80
Deutschen Mineraloelwirtschaft, Jahrbuch der. Karl-Heinrich v. Thurmen. Review by E. A. Eckhardt	1	103
Development, The History and, of Seismic Prospecting. B. B. Weatherby	3	215
Direct Method of Interpretation in Resistivity Prospecting. C. L. Pekeris	1	31
Discussions and Communications. Note on the Change in Frequency of the Reflection from Basement as this Reflecting Horizon Increases in Depth. Sidon Harris and N. A. Haskell	2	194
Eckhardt, E. A. A Brief History of the Gravity Method of Prospecting for Oil	3	231
———. Partnership between Geology and Geophysics in Prospecting for Oil	3	209
———. Review of *Jahrbuch der Deutschen Mineraloelwirtschaft*, by Karl-Heinrich v. Thurmen	1	103
Education, Geophysical, in a Department of Geophysics. James B. Macelwane, S.J.	1	80

	No.	Page
———, Geophysics, at an Engineering Institution. Dart Wantland	1	91
Elastic Media, Reflection and Transmission, Coefficients for Plane Waves in. M. Muskat and M. W. Meres	2	115
———, Waves in the Earth, Propagation of. L. G. Howell, C. H. Kean, and R. R. Thompson	1	1
Election, 1940—Ballot	1	111
Electrical Prospecting Methods, Typical. W. M. Rust, Jr.	3	243
Elkins, Thomas A. The Reliability of Geophysical Anomalies on the Basis of Probability Considerations	4	321
Eltran Electrode Configuration, Three-Layer Resistivity Curves for the. S. S. West	1	43
Engineering Institution, Geophysics Education at an. Dart Wantland	1	91
———, Mathematical Methods in. Theodore v. Karman and Maurice A. Biot. Review by Morris Muskat	2	196
Evidence, Additional, on the Relation of Temperature to Structure in the Salt Creek Oil Field, Natrona County, Wyoming. C. E. Van Orstrand	1	47
Experimental Device for Computing Magnetic and Gravitational Anomalies, An. J. W. Fisher	1	22
Exploration, Chemical, Some Neglected Aspects of. R. Thomas Sanderson	3	284
———, for Petroleum, A Perspective of. E. E. Rosaire	3	259
——— of the United States and Canada, 1924–1939, Fifteen Years of Geophysics: A Chapter in the. James B. Macelwane, S.J.	3	250
Fearon, R. E., and Green, W. G. Well Logging by Radioactivity	3	272
Fifteen Years of Geophysics: A Chapter in the Exploration of the United States and Canada, 1924–1939. James B. Macelwane, S.J.	3	250
Fisher, J. W. An Experimental Device for Computing Magnetic and Gravitational Anomalies	1	22
Form and Nature of Seismic Waves and the Structures of Seismograms, The. Norman Ricker	4	348
Formulas and Curves for the Interpretation of Certain Two-Dimensional Magnetic and Gravitational Anomalies. Harold H. Pentz	3	295
Gay, M. W. Relative Gravity Measurements Using Pendulum Equipment	2	176
Geology and Geophysics in Prospecting for Oil, Partnership between. E. A. Eckhardt	3	209
Geophone Depth, Change of Reflection Amplitude and Character with. H. M. Houghton	2	169
Geophysical Anomalies, The Reliability of, on the Basis of Probability Considerations. Thomas A. Elkins	4	321
——— Education in a Department of Geophysics. James B. Macelwane, S.J.	1	80
Geophysics Education at an Engineering Institution. Dart Wantland	1	91
———, Fifteen Years of: A Chapter in the Exploration of the United States and Canada, 1924–1939. James B. Macelwane, S.J.	3	250
———, Geophysical Education in a Department of. James B. Macelwane, S.J.	1	80
———, Partnership between Geology and, in Prospecting for Oil. E. A. Eckhardt	3	209
Geothermal Methods of Estimating the Age of the Earth. C. E. Van Orstrand	1	57
Gravitational Anomalies, Certain Two-Dimensional Magnetic and, Formulas and Curves for the Interpretation of. Harold H. Pentz	3	295
——— Anomalies, Magnetic and, An Experimental Device for Computing, J. W. Fisher	1	22
Gravity Measurements, Relative, Using Precision Pendulum Equipment. M. W. Gay	2	176
——— Method of Prospecting for Oil, A Brief History of the. E. A. Eckhardt	3	231
Green, W. G., and Fearon, R. E. Well Logging by Radioactivity	3	272

	No.	Page
Harris, Sidon, and Haskell, N. A. Discussions and Communications—Note on the Change in Frequency of the Reflection from Basement as this Reflecting Horizon Increases in Depth	2	194
Haskell, N. A., and Harris, Sidon. Discussions and Communications—Note on the Change in Frequency of the Reflection from Basement as this Reflecting Horizon Increases in Depth	2	194
———, and Widess, M. B. The Computation and Mapping of Seismic Reflection Data	2	156
History and Development of Seismic Prospecting, The. B. B. Weatherby	3	215
——— of the Gravity Method of Prospecting for Oil, A Brief. E. A. Eckhardt	3	231
Horizons, Stratified, The Seismic Wave Energy Reflected from Various Types of. M. Muskat and M. W. Meres	2	149
Houghton, H. M. Change of Reflection Amplitude and Character with Geophone Depth	2	169
Howell, L. G., Keen, C. H., and Thompson, R. R. Propagation of Elastic Waves in the Earth	1	1
Index of Society Publications, 1931–1939	3	Part 2, 1
Institution, Engineering, Geophysics Education at an. Dart Wantland	1	91
Interpretation in Resistivity Prospecting, Direct Method of. C. L. Pekeris	1	31
——— of Certain Two-Dimensional Magnetic and Gravitational Anomalies, Formulas and Curves for the. Harold H. Pentz	3	295
Jahrbuch der Deutschen Mineraloelwirtschaft, by Karl-Heinrich v. Thurmen. Review by E. A. Eckhardt	1	103
Kamen-Kaye, M. Seismic Refraction Studies in the Orinoco Basin of Deposition, Venezuela	4	385
Karman, Theodore v., and Biot, Maurice A. Mathematical Methods in Engineering. Review by Morris Muskat	2	196
Kean, C. H., Howell, L. G., and Thompson, R. R. Propagation of Elastic Waves in the Earth	1	1
LeMay, Raymond Andrew—Memorial. E. E. Rosaire	2	192
Lynton, Edward D. Magnetic Core Orientation—The Mechanics of the Upside Down Core	4	393
Macelwane, James B., S.J. Fifteen Years of Geophysics: A Chapter in the Exploration of the United States and Canada, 1924–1939	3	250
———. Geophysical Education in a Department of Geophysics	1	80
Magnetic and Gravitational Anomalies, An Experimental Device for Computing. J. W. Fisher	1	22
——— and Gravitational Anomalies, Certain Two-Dimensional, Formulas and Curves for the Interpretation of, Harold H. Pentz	3	295
——— Core Orientation—The Mechanics of the Upside Down Core. Edward D. Lynton	4	393
Mapping, The Computation and, of Seismic Reflection Data. M. B. Widess and N. A. Haskell	2	156
Mathematical Methods in Engineering. Theodore v. Karmen and Maurice A. Biot. Review by Morris Muskat	2	196
McCready, H. J. Shot Hole Characteristics in Reflection Seismology	4	373
Mechanics of the Upside Down Core, The—Magnetic Core Orientation. Edward D. Lynton	4	393
Meeting, 1940 Annual, Announcement of	1	108
———, 1941 Annual, Announcement of	3	310
———, 1941 Annual, Announcement of	4	408
———, Annual Business, Minutes of	2	201

	No.	Page
———, The Tenth Annual, of the Society of Exploration Geophysicists	2	201
———, 1940 Fall, Cancellation of	3	310
Membership Applications Approved for Publication	1	109
——— Applications Approved for Publication	3	310
——— Applications Approved for Publication	4	408
——— List of the Society of Exploration Geophysicists, October 1, 1940	4	422
Memorial—Ernest Eugene Blondeau. B. B. Weatherby	1	102
——— —Raymond Andrew LeMay. E. E. Rosaire	2	192
Meres, M. W., and Muskat, M. Reflection and Transmission Coefficients for Plane Waves in Elastic Media	2	115
———, and Muskat, M. The Seismic Wave Energy Reflected from Various Types of Stratified Horizons	2	149
Methods, Geothermal, of Estimating the Age of the Earth. C. E. Van Orstrand	1	57
Michigan Weathering. N. N. Zirbel	4	382
Muskat, Morris. Review of Mathematical Methods in Engineering, by Theodore v. Karman and Maurice A. Biot	2	196
———, and Meres, M. W. Reflection and Transmission Coefficients for Plane Waves in Elastic Media	2	115
———, and Meres, M. W. The Seismic Wave Energy Reflected from Various Types of Stratified Horizons	2	149
Natrona County, Wyoming, Salt Creek Oil Field, Additional Evidence on the Relation of Temperature to Structure in the. C. E. Van Orstrand	1	47
Nature of Seismic Waves, The Form and, and the Structure of Seismograms. Norman Ricker	4	348
Note on the Change in Frequency of the Reflection from Basement as this Reflecting Horizon Increases in Depth, Discussions and Communications. Sidon Harris and N. A. Haskell	2	194
Observations, Tidal Force. Alfred Wolf	4	317
Oleson, Raymond, and Washburn, Harold. Transient Testing of Seismic Recording Apparatus	4	337
Orinoco Basin of Deposition, Venezuela, Seismic Refraction Studies in the M. Kamen-Kaye	4	385
Partnership between Geology and Geophysics in Prospecting for Oil. E. A. Eckhardt	3	209
Patents	1	104
———	2	198
———	3	307
———	4	404
Pekeris, C. L. Direct Method of Interpretation in Resistivity Prospecting	1	31
Pendulum Equipment, Precision, Relative Gravity Measurements Using. M. W. Gay	2	176
Pentz, Harold H. Formulas and Curves for the Interpretation of Certain Two-Dimensional Magnetic and Gravitational Anomalies	3	295
Personal Items	1	112
——— Items	2	206
——— Items	3	314
——— Items	4	410
Petroleum, A Prospective of Exploration for. E. E. Rosaire	3	259
Plane Waves in Elastic Media, Reflection and Transmission Coefficients for. M. Muskat and M. W. Meres	2	115
Probability Considerations, The Reliability of Geophysical Anomalies on the Basis of. Thomas A. Elkins	4	321
Propagation of Elastic Waves in the Earth. L. G. Howell, C. H. Kean, and R. R. Thompson	1	1

	No.	Page
Prospecting for Oil, A Brief History of the Gravity Method of. E. A. Eckhardt	3	231
——— for Oil, Partnership between Geology and Geophysics in. E. A. Eckhardt	3	209
——— Methods, Typical Electrical. W. M. Rust, Jr.	3	243
———, Resistivity, Direct Method of Interpretation in. C. L. Pekeris	1	31
———, Seismic, The History and Development of. B. B. Weatherby	3	215
Radioactivity, Well Logging by. W. G. Green and R. E. Fearon	3	272
Recording Apparatus, Seismic, Transient Testing of. Harold Washburn and Raymond Oleson	4	337
Reflection Amplitude and Character, Change of, with Geophone Depth. H. M. Houghton	2	169
——— and Transmission Coefficients for Plane Waves in Elastic Media. M. Muskat and M. W. Meres	2	115
——— Data, Seismic, The Computation and Mapping of. M. B. Widess and N. A. Haskell	2	156
——— from Basement, Note on the Change in Frequency of the, as this Reflection Horizon Increases in Depth. Sidon Harris and N. A. Haskell	2	196
——— Seismology, Shot Hole Characteristics in. J. J. McCready	4	373
Refraction Studies, Seismic, in the Orinoco Basin of Deposition, Venezuela. M. Kamen-Kaye	4	385
Relation of Temperature to Structure in the Salt Creek Oil Field, Natrona County, Wyoming, Additional Evidence on the. C. E. Van Orstrand	1	47
Relative Gravity Measurements Using Precision Pendulum Equipment. M. W. Gay	2	176
Reliability of Geophysical Anomalies on the Basis of Probability Considerations, The. Thomas A. Elkins	4	321
Report, Annual, of the Secretary-Treasurer	2	202
Resistivity Curves, Three-Layer, for the Eltran Electrode Configuration. S. S. West	1	43
——— Prospecting, Direct Method of Interpretation in. C. L. Pekeris	1	31
Reviews—*Jahrbuch der Deutschen Mineraloelwirtschaft*, by Karl-Heinrich v. Thurmen. E. A. Eckhardt	1	103
——— —Mathematical Methods in Engineering, by Theodore v. Karman and Maurice A. Biot. Morris Muskat	2	196
——— Announcement of New Books		403
Ricker, Norman. The Form and Nature of Seismic Waves and the Structure of Seismograms	4	348
Rosaire, E. E. A Perspective of Exploration for Petroleum	3	259
———. Memorial—Raymond Andrew LeMay	2	192
Round Table, The Society	1	108
——— Table, The Society	2	201
——— Table, The Society	3	310
——— Table, The Society	4	408
Rust, W. M., Jr., Typical Electrical Prospecting Methods	3	243
Salt Creek Oil Field, Natrona County, Wyoming, Additional Evidence on the Relation of Temperature to Structure in the. C. E. Van Orstrand	1	47
Sanderson, R. Thomas. Some Neglected Aspects of Chemical Exploration	3	284
Secretary-Treasurer, Annual Report of the	2	202
Seismic Prospecting, The History and Development of. B. B. Weatherby	3	215
——— Recording Apparatus, Transient Testing of. Harold Washburn and Raymond Oleson	4	337
——— Reflection Data, The Computation and Mapping of. M. B. Widess and N. A. Haskell	2	156
——— Refraction Studies in the Orinoco Basin of Deposition, Venezuela. M. Kamen-Kaye	4	385

	No.	Page
——— Wave Energy Reflected from Various Types of Stratified Horizons, The. M. Muskat and M. W. Meres	2	149
——— Waves, The Form and Nature of, and the Structure of Seismograms. Norman Ricker	4	348
Seismology, Reflection, Shot Hole Characteristics in. H. J. McCready	4	373
Seismograms, The Form and Nature of Seismic Waves and the Structure of. Norman Ricker	4	348
Shot Hole Characteristics in Reflection Seismology. H. J. McCready	4	373
Some Neglected Aspects of Chemical Exploration. R. Thomas Sanderson	3	284
Stratification, Velocity, as an Aid to Correlation. Roland F. Beers	1	15
Stratified Horizons, The Seismic Wave Energy Reflected from Various Types of. M. Muskat and M. W. Meres	2	149
Structure, Additional Evidence on the Relation of Temperature to, in the Salt Creek Oil Field, Natrona County, Wyoming. C. E. Van Orstrand	1	47
——— of Seismograms, The Form and Nature of Seismic Waves and the. Norman Ricker	4	348
Temperature, Additional Evidence on the Relation of, to Structure in the Salt Creek Oil Field, Natrona County, Wyoming. C. E. Van Orstrand	1	47
Testing, Transient, of Seismic Recording Apparatus. Harold Washburn and Raymond Oleson	4	337
Thompson, R. R., Howell, L. G., and Keen, C. H. Propagation of Elastic Waves in the Earth	1	1
Three-Layer Resistivity Curves for the Eltran Electrode Configuration. S. S. West	1	43
Thurmen, Karl-Heinrich v. *Jahrbuch der Deutschen Mineraloelwirtschaft.* Review by E. A. Eckhardt	1	103
Tidal Force Observations. Alfred Wolf	4	317
Time Delay of a Wave Group in the Weathered Layer, The. Alfred Wolf	4	367
Transient Testing of Seismic Recording Apparatus. Harold Washburn and Raymond Oleson	4	337
Transmission, Reflection and, Coefficients for Plane Waves in Elastic Media. M. Muskat and M. W. Meres	2	115
Two-Dimensional Magnetic and Gravitational Anomalies, Formulas and Curves for the Interpretation of Certain. Harold H. Pentz	3	295
Typical Electrical Prospecting Methods. W. M. Rust, Jr.	3	243
Upside Down Core, Magnetic Core Orientation—The Mechanics of the. Edward D. Lynton	4	393
Van Orstrand, C. E. Additional Evidence on the Relation of Temperature to Structure in the Salt Creek Oil Field, Natrona County, Wyoming	1	47
———. Geothermal Methods of Estimating the Age of the Earth	1	57
Velocity Stratification as an Aid to Correlation. Roland F. Beers	1	15
Venezuela, Orinoco Basin of Deposition, Seismic Refraction Studies in the. M. Kamen-Kaye	4	385
Wantland, Dart. Geophysics Education at an Engineering Institution	1	91
Washburn, Harold, and Oleson, Raymond. Transient Testing of Seismic Recording Apparatus	4	337
Wave Energy, The Seismic, Reflected from Various Types of Stratified Horizons. M. Muskat and M. W. Meres	2	149
——— Group, The Time Delay of a, in the Weathered Layer. Alfred Wolf	4	367
Waves, Elastic, Propagation of, in the Earth. L. G. Howell, C. H. Kean, and R. R. Thompson	1	1
———, Plane, Reflection and Transmission Coefficients for, in Elastic Media. M. Muskat and M. W. Meres	2	115

	No.	Page
———, Seismic, The Form and Nature of, and the Structure of Seismograms. Norman Ricker	4	348
Weatherby, B. B. Memorial—Ernest Eugene Blondeau	1	102
———. The History and Development of Seismic Prospecting	3	215
Weathered Layer, The Time Delay of a Wave Group in the. Alfred Wolf	4	367
Weathering, Michigan. N. N. Zirbel	4	382
Well Logging by Radioactivity. W. G. Green and R. E. Fearon	3	272
West, S. S. Three-Layer Resistivity Curves for the Eltran Electrode Configuration	1	43
Widess, M. B., and Haskell, N. A. The Computation and Mapping of Seismic Reflection Data	2	156
Wolf, Alfred. The Time Delay of a Wave Group in the Weathered Layer	4	367
———. Tidal Force Observations	4	317
Wyoming, Additional Evidence on the Relation of Temperature to Structure in the Salt Creek Oil Field, Natrona County. C. E. Van Orstrand	1	47
Zirbel, N. N. Michigan Weathering	4	382

Volume V OCTOBER, 1940 Number 4

GEOPHYSICS

A Journal of General and Applied Geophysics

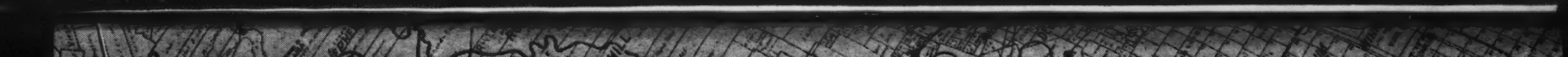
Published by

The Society of Exploration Geophysicists

CONTENTS

Tidal Force Observations	*Alfred Wolf*	317
The Reliability of Geophysical Anomalies on the Basis of Probability Considerations	*Thomas A. Elkins*	321
Transient Testing of Seismic Recording Apparatus	*Harold Washburn ad Raymond Olesen*	337
The Form and Nature of Seismic Waves and the Structure of Seismograms	*Norman Ricker*	348
The Time Delay of a Wave Group in the Weathered Layer	*Alfred Wolf*	367
Shot Hole Characteristics in Reflection Seismology	*H. J. McCready*	373
Michigan Weathering	*N. N. Zirbel*	382
Seismic Refraction Studies in the Orinoco Basin of Deposition, Venezuela	*M. Kamen-Kaye*	385
The Mechanics of the Upside Down Core	*Edward D. Lynton*	393
Discussions and Communications		402
Reviews		403
Patents		404
The Society Round Table		
Annual Meeting		408
Membership Applications Approved for Publication		408
Personal Items		410
Constitution and By-Laws		413
Membership List		422
Index to Volume V		447

IXO
POINTING THE WAY FOR THE DRILL
Offering TWO EXPLORATION Services
Independent Exploration Company offers its clients two efficient and economical exploration services, for two distinctly different purposes.
GRAVITY SURVEYS, using the new IX Gravity meter, for rapid, low-cost reconnaissance with adequate coverage.
SEISMOGRAPH SURVEYS, using the improved IX reflection seismograph equipment, for accurate detailing and depth determination.
Gravity and seismograph crews are available for operation in any part of the world where U. S. passports are honored.
Write for further details
INDEPENDENT
EXPLORATION COMPANY
POINTING THE WAY FOR THE DRILL
2011 ESPERSON BLDG. HOUSTON, TEXAS
Experienced in 24 States and 4 Foreign Fields



THE SOCIETY OF EXPLORATION GEOPHYSICISTS

OFFICERS FOR THE YEAR ENDING MARCH 1941

W. T. BORN ..... *President*
Geophysical Research Corporation, Tulsa, Oklahoma

H. B. PEACOCK ..... *Vice-President*
Geophysical Service, Inc., Houston, Texas

ANDREW GILMOUR ..... *Secretary-Treasurer*
Geophysical Research Corporation, Tulsa, Oklahoma

R. D. WYCKOFF ..... *Editor*
Gulf Research & Development Company
Pittsburgh, Pennsylvania

E. A. ECKHARDT ..... *Past-President*
Gulf Research & Development Company
Pittsburgh, Pennsylvania

GEOPHYSICS is the official publication of the Society of Exploration Geophysicists and is published four times a year, January, April, July and October. $3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, GEOPHYSICS. The subscription rate to non-members is $6.00 per year (plus 50 cents additional for postage to foreign addresses).

Requests for information on applications for membership, claims for non-receipt of numbers, subscriptions, and all other business matters should be sent to the Business Manager of the Society: J. F. Gallie, 450 Ahnaip Street, Menasha, Wisconsin, or P.O. Box 777, Austin, Texas. Claims for non-receipt of preceding numbers of GEOPHYSICS must be sent to the Business Manager within three months of the date of publication in order to be filled gratis.

Editorial matters should be sent to the Editor of the Society: R. D. Wyckoff, Gulf Research & Development Company, P.O. Box 2038, Pittsburgh, Pennsylvania.

Back numbers prior to 1935 are out of print. The following copies are available at $2.00 per copy to members of the Society and $3.00 per copy to non-members (20 cents additional if mailed to foreign addresses):

1935 Vol. VI, No. 1, JOURNAL OF THE SOCIETY OF PETROLEUM GEOPHYSICISTS.
1936 Vol. I, Nos. 2, 3, GEOPHYSICS (No. 1, out of print).
1937 Vol. II, Nos. 1, 2, 3, 4, GEOPHYSICS.
1938 Vol. III, Nos. 1, 2, 3, 4, GEOPHYSICS.
1939 Vol. IV, Nos. 1, 2, 3, 4, GEOPHYSICS.

Orders for subscriptions or back numbers should be sent to J. F. Gallie, Business Manager, 450 Ahnaip Street, Menasha, Wisconsin, or P.O. Box 777, Austin, Texas.

Entered as second-class matter September 7, 1938 at the post office at Menasha, Wisconsin, under the Act of March 3, 1879.

Copyright 1940, By the Society of Exploration Geophysicists.

The Society of Exploration Geophysicists

Society: The Society of Petroleum Geophysicists was organized in 1930 at Houston, Texas. In 1936, the Society approved a change in name to the Society of Exploration Geophysicists, to indicate the close association of the aims and objects of the Society with the newly recognized primary function of Exploration, which has recently been recognized by the petroleum industry as being on a par with Production, Transportation, Refining, and Marketing.

Aims and Objects: The Society functions for the promotion of the science of geophysics, especially as it relates to petroleum geology and to the discovery and production of oil and natural gas and associated minerals, and the maintenance of a high professional standard among its members. Among the methods of accomplishing these objectives is the publication of papers, discussions, and communications of interest to the membership.

Journal: GEOPHYSICS is the official publication of the Society, and in it are published all of the papers, discussions, and communications received from the membership which are accepted for publication by the Editor. Copies are sent to all members of the Society in good standing. $3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, *Geophysics*. The subscription price to non-members is $6.00 per year, with an additional charge for postage where such is necessary. Claims for non-receipt of preceding numbers of GEOPHYSICS must be sent to the Business Manager within three months of the date of publication in order to be filled gratis.

Responsibility: It is understood that the statements and opinions given in GEOPHYSICS are views of the individual authors to whom they are credited, and are not binding on the membership of the Society as a whole. Papers submitted to the Society for publication shall be regarded as no longer confidential.

Reprinting Journal Material: The right to reprint portions or abstracts of the papers, discussions, or notes in GEOPHYSICS is granted on the express condition that special reference shall be made to the source of such material. Diagrams and photographs published in GEOPHYSICS may not be reproduced without making special arrangements with the Society through the Editor.

Manuscripts: All manuscripts submitted for publication should be sent directly to the Editor. They will be examined by the Editor and such special editors or reviewers as he may appoint to determine their suitability for publication in GEOPHYSICS. Authors are advised as promptly as possible of the action taken, usually within two or three months. Manuscripts and illustrations will be destroyed immediately after publication of the paper unless the author requests their return.

Discussion: The Editor invites discussion of papers published in GEOPHYSICS. Such discussion will remain open until closed by the Editor.

Form of Manuscript: Papers are published in English only. To be acceptable for publication, manuscript should be original typewritten copy (not carbon copy), either double or triple spaced, with wide margins. References should appear as footnotes only and should be numbered consecutively to avoid repetition. References should include author's name, journal, volume number, page number and year, and should be listed in the order given here. Attention should be given to captions for tables and legends for figures. These in all cases should be complete in themselves so as to make the data intelligible to the reader without consulting the text of the article. "Figure" should be used rather than "Plate" for illustrations.

Special care should be given to mathematical expressions. The very simplest formulas only should be typewritten and all others carefully written in with pen and ink. Fractional exponents should be used everywhere to avoid root signs. Extra symbols should be used to avoid complicated exponents. The solidus (/) should be used wherever possible for fractions.

All illustrations should accompany manuscript and should always be referred to in the text. Line drawings must be made with India ink on plain white paper or on tracing cloth. Coordinate paper is not desirable, but if used must be blue-lined with all coordinates to be reproduced drawn with India ink. Lettering should be of sufficient size to be legible after reduction.

Proof and all correspondence covering papers in the process of publication should be addressed to the Editor.

Abstracts: An abstract must accompany each article. It should be adequate as an index and as a summary. As an index it should give all subjects, major and minor, concerning which new information is presented. As a summary it should give the conclusions of the article and all numerical results of general interest.

Subscriptions: Subscriptions, renewals, and orders for back numbers should be addressed to the Business Manager, J. F. Gallie, 450 Ahnaip Street, Menasha, Wisconsin, or P.O. Box 777, Austin, Texas.

Reprints: GEOPHYSICS furnishes reprints, with covers if desired, at cost plus a handling charge of about 15%. Orders for reprints should accompany corrected galley proof.

Advertising: Rates for advertising will be furnished by the Business Manager on application.

R. D. WYCKOFF, *Editor*
Gulf Research & Development Company
P.O. Box 2038, Pittsburgh, Pennsylvania

PULL OUT

WITH

KING POWER WINCHES

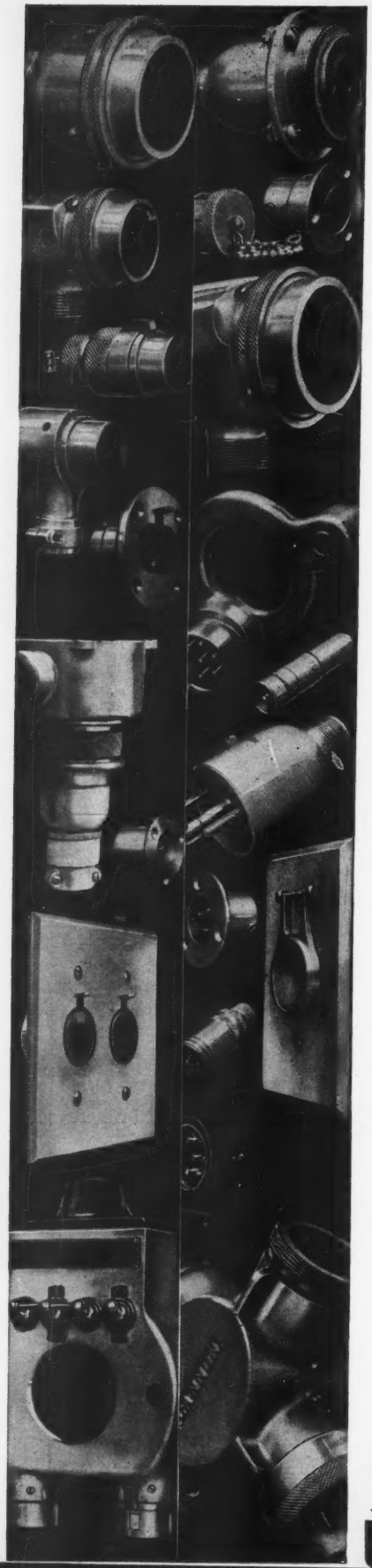
MODEL 125 KING Winch on 1½-ton truck.
Note strong bumper and platform.

In addition to Model 125 Winch, we manufacture Model 120, for ¾ and 1 ton trucks. These two models are driven from power take-offs. We manufacture special take-offs also.

Our Model 100 Power Winch is driven from the front end of crank shaft. It is made for ½ ton trucks and for passenger cars.

Write for literature and prices.

KOENIG IRON WORKS
2214 WASHINGTON AVE., HOUSTON, TEXAS



Successful . . .

Interpretations Depend on

ACCURATE ELECTRICAL RECORDINGS

CANNON Cable Connectors insure perfect cable and wire connections and guarantee a constant flow of the low-level current without which accurate recordings are impossible. Efficient field operations and successful interpretations depend entirely on correct recordings.

CANNON Plugs are pre-eminent in Geophysical Research and other technical fields because of their efficiency, ruggedness and dependability. The Cannon Company devotes its energy almost exclusively to the manufacture of Cable Connectors for Motion Picture Service, Geophysical Research, Aircraft, Radio Broadcasting, Instrument-Control on Ships and Power Circuits.

Every Cannon product is backed by more than 25 years of manufacturing experience under the same management. The Cannon line embodies the greatest variety of Plugs and Receptacles offered by any manufacturer in the world. Illustrated Bulletins describe CANNON Plugs in detail. Ask for your copy.

When requesting Bulletins, please specify your requirements.

•

CANNON ELECTRIC DEVELOPMENT CO.
★ 420 West Avenue 33, Los Angeles, California.
★ *EASTERN SALES OFFICE*, 220 Fifth Ave., New York, N.Y.

CANNON PLUGS

Robert H. Ray, Inc.

GEOPHYSICAL ENGINEERING
SPECIALIZING GRAVITY SURVEYS
AND
INTERPRETATION

CONTRACTING
CONSULTING

Foreign—Domestic

GULF BLDG.
HOUSTON, Tex.

CABLE
"ROBRAY"

A Complete Compilation of Modern Geophysical Techniques

EXPLORATION GEOPHYSICS

By J. J. Jakosky, Sc. D.

This authoritative volume of approximately 800 pages and 430 illustrations describes the fundamental theories, equipment and field techniques of the recognized exploratory geophysical methods and illustrates their application to problems of economic geology. Concisely and clearly written, it is a valuable book for geophysicists; geologists; teachers; physicists; petroleum, mining and civil engineers; supervisors and production men of oil and mining companies; supervisors and directors of public works; patent attorneys; prospectors, etc. Unequalled in completeness of authoritative information and clarity of expression.

CHAPTERS

1. INTRODUCTION: HISTORY OF GEOPHYSICAL EXPLORATION. 2. GEOLOGIC AND ECONOMIC BACKGROUND OF EXPLORATION GEOPHYSICS. 3. MAGNETIC METHODS. 4. GRAVITATIONAL METHODS. 5. ELECTRICAL, POTENTIAL AND RESISTIVITY METHODS. 6. ELECTRICAL, MAGNETOMETRIC AND INDUCTIVE METHODS. 7. SEISMIC METHODS: WAVE PROPAGATION. REFLECTION METHODS; DIP, CORRELATION AND VELOCITY SHOOTING. REFRACTION METHODS. INSTRUMENTS. EQUIPMENT. FIELD OPERATIONS. 8. GEOCHEMICAL METHODS. 9. GEOTHERMAL METHODS. 10. BORE HOLE SURVEYING METHODS. 11. PHYSICAL PRINCIPLES APPLIED TO PRODUCTION PROBLEMS. 12. COMMON PERMIT AND TRESPASS PRACTICES: INSURANCE.

EXPLORATION GEOPHYSICS differs greatly from other texts on geophysics because of its clear exposition, its detailed and practical descriptions of contemporary geophysical techniques and instruments, and in the large number of examples from commercial surveys. New and original, easy to read . . . the outstanding book of modern geophysical exploration.

Thirty-Two Collaborators And Critics

Each chapter of EXPLORATION GEOPHYSICS was prepared in collaboration with geophysicists with extensive experience in their particular geophysical techniques. Their excellent cooperation makes the book up-to-the-minute in every detail.

MAIL COUPON TODAY

Times-Mirror Press, 110 South Broadway, Los Angeles, California: Please send me a copy of EXPLORATION GEOPHYSICS on 5 days approval. If I find that this is not the leading book of modern geophysical exploration, I will return it postpaid within that time, and you will immediately refund the purchase price.

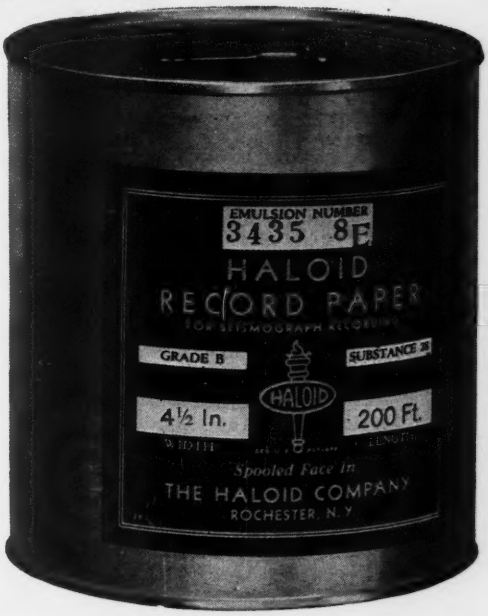
Name .....City & State .....

Street & No. .....Position .....

Firm .....

Please mention GEOPHYSICS when answering advertisers

"We Prefer HALOID RECORD For Finer Recordings Under Adverse Conditions"



HALOID RECORD

For Uniform Performance and Minimum Waste

Finer Recordings and Minimum Waste **. . . under extremes of heat and humidity . . . are the reasons why more and more geophysicists are depending on Haloid Record.**

We're confident one can of Haloid Record will prove that its uniformly fast exposure and rapid free development cut waste to a minimum . . . offer easy manipulation. Contrast is exceptional. Sharp whites are clearly legible against dense jet blacks. Base stock has greater wet strength. Sheen and curl are reduced to a minimum.

That's why we'd like to send you several cans of Haloid Record to test under your own conditions. ***No obligation, of course.*** **Just write specifying your regular size. (Maximum, in cans, 8" x 200'.)**

THE HALOID COMPANY, 103 Haloid St., ROCHESTER, N.Y.

HALOID RECORD

for Superior Geophysical Recordings

PETTY

★

Fifteen Years
Seismograph Work
With No
Dissatisfied Clients

★

PETTY GEOPHYSICAL ENGINEERING CO.

SAN ANTONIO, TEXAS

Now Available: Gravity Surveys

PETTY GRAVITY SURVEYS, Inc.

GEOPHYSICS ADVERTISERS

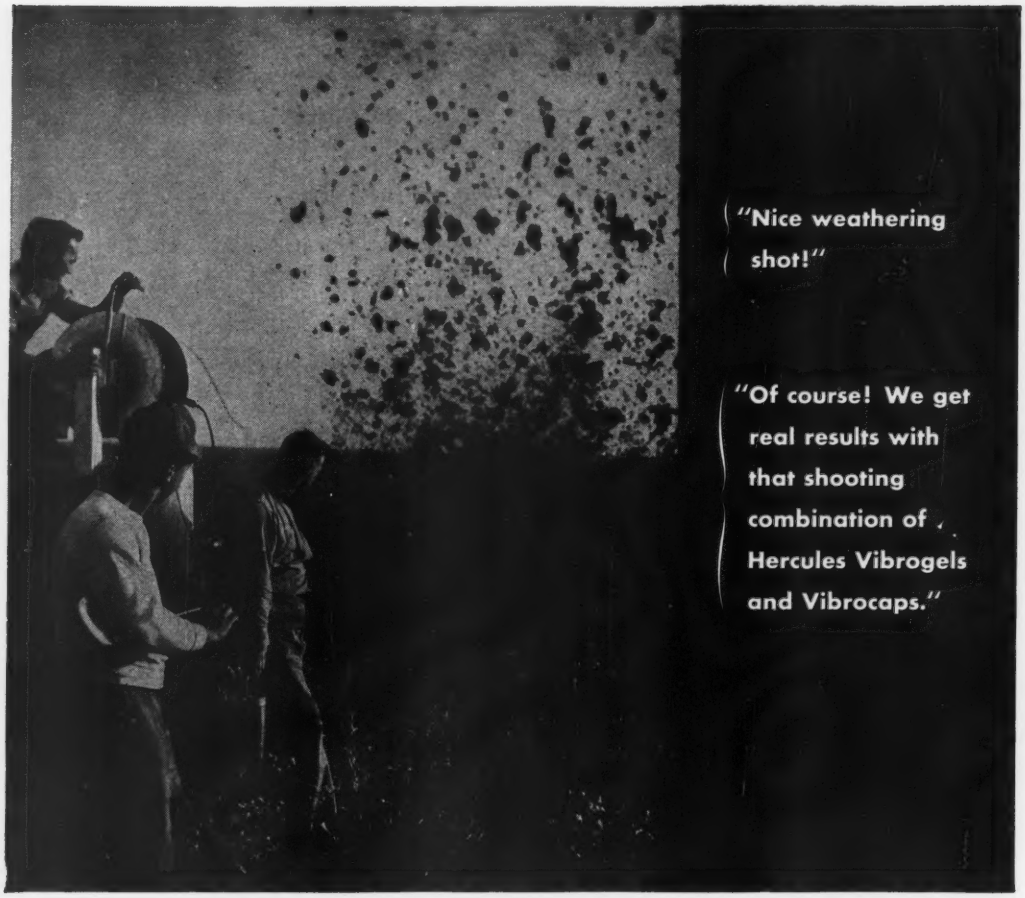
American Askania Corporation .....
American Association of Petroleum Geologists 18
American Institute of Physics 21
American Paulin System .....
Atlas Powder Company .....
William M. Barret, Inc. 20
Burgess Battery Company .....
Cannon Electric Development Company .. 4
E. I. du Pont de Nemours & Company, Inc. 28
Eastman Kodak Company 15
Economic Geology Publishing Company .. 24
Engineering Laboratories, Inc. .....
Geophysical Prospecting for Oil 21
Exploration Geophysics 6
George E. Failing Supply Company 26
Ferranti Electric, Inc. .....
Geophysical Service, Inc. ....*Inside back cover*
Geophysical Engineering Corporation ....
Geotechnical Corporation 16
H. P. Gott Manufacturing Company .....
Gravity Meter Exploration Co. 24
Hall Manufacturing Company .....
Haloid Company 7
Hercules Powder Company 10
Illinois Powder Manufacturing Company . 24
Independent Exploration Company .....
.....*Inside front cover*
Koenig Iron Works 3
Lane-Wells Company 16
Hans Lundberg Limited 24
C. D. Lockwood's Texas Oil Report .....
McGraw-Hill Book Company, Inc. 21
Nelson Electric Supply Company 16
Petty Geophysical Engineering Company . 8
Robert H. Ray, Inc. 5
Schlumberger Well Surveying Corporation 19
Seismic Explorations, Inc. 17
Seismograph Service Corporation 27
Sperry-Sun Well Surveying Company ...
Subterrex .....*Outside back cover*
Thomas & Skinner Steel Products Company .....
Thompson Tool Company .....
Times-Mirror Press 6
Torsion Balance Exploration Co. 24
United Geophysical Company 23
Western Geophysical Company 25
S. S. White .....
World Petroleum 22

PROFESSIONAL CARDS

Joseph L. Adler 11
Roland F. Beers 12
Elmer W. Ellsworth 12
T. I. Harkins 12
J. O. Hoard 13
Leo Horvitz 13
John S. Ivy 11
J. C. Karcher 12
H. Klaus 12
J. L. Lake 13
Andrew M. MacMahon 13
Chas. Gill Morgan 12
L. M. Mott-Smith 13
W. W. Newton 11
H. B. Peacock 11
Robert H. Ray 13
F. F. Reynolds 13
E. E. Rosaire 11
Henry Salvatori 12
Joshua L. Soske 13
John H. Wilson 11

THE ELEVENTH ANNUAL MEETING

of the Society of Exploration Geophysicists will be held April 1-3, 1941, in Houston, Texas, concurrently with the twenty-sixth annual convention of the American Association of Petroleum Geologists. Plan now to attend.


"Nice weathering shot!"
"Of course! We get real results with that shooting combination of Hercules Vibrogels and Vibrocaps."

VIBROGEL

VIBROCAP

Registered trade-marks U. S. Pat. Off.

HERCULES POWDER COMPANY
Incorporated
917 KING STREET
WILMINGTON, DELAWARE

M-13-A

PROFESSIONAL DIRECTORY

Space reserved for members only. For rates
apply to J. F. Gallie
P.O. Box 777, Austin, Texas

E. E. ROSAIRE
Geochemical Prospecting

SUBTERREX

701 Waugh Drive, Houston, Texas.

JOHN H. WILSON
Geologist and Geophysicist

Independent Exploration Company
2015 Fort Worth National Bank Building
FORT WORTH, TEXAS

JOHN S. IVY
Union Producing Company

SHREVEPORT, LOUISIANA

JOSEPH L. ADLER
Geologist and Geophysicist

Independent Prospecting Co.
2011 Esperson Bldg., Houston, Texas

W. W. NEWTON

1702 Tower Petroleum Building

DALLAS, TEXAS

H. B. PEACOCK
Geophysical Service, Inc.

825 Esperson Building
HOUSTON, TEXAS

J. C. KARCHER

Continental Building
DALLAS, TEXAS

ROLAND F. BEERS

1702 Tower Petroleum Building
DALLAS, TEXAS

ELMER W. ELLSWORTH
Geologist and Geophysicist

Wham Building
212 East Broadway
CENTRALIA, ILLINOIS

HENRY SALVATORI

Western Geophysical Company

711 Edison Building
601 West Fifth Street
LOS ANGELES, CALIFORNIA

T. I. HARKINS

Independent Exploration Company

2011 Esperson Building
Houston, Texas

H. KLAUS
Geologist and Geophysicist

KLAUS EXPLORATION CO.
Torsion Balance Surveys
and Interpretations

ENID, OKLA.
P.O. Box 662

LUBBOCK, TEXAS
P.O. Box 1617

CHAS. GILL MORGAN
Geologist and Geophysicist

UNITED GEOPHYSICAL COMPANY

Pasadena, California

LEO HORVITZ
Geochemist
SUBTERREX LABORATORIES
701 Waugh Drive
Houston, Texas

JOSHUA L. SOSKE
GEOPHYSICAL ENGINEERING CORPORATION
199 South Fair Oaks Avenue
PASADENA, CALIFORNIA

J. L. LAKE
Geophysicist
SUBTERREX
701 Waugh Drive
Houston, Texas

J. O. HOARD
HOARD EXPLORATION COMPANY
Esperson Building Houston, Texas

ANDREW M. MacMAHON
Physicist and Mathematician
820 Union National Bank Building
Telephone: Fairfax 1720
HOUSTON, TEXAS
Industrial Research Instrument Design
Patent Development Geophysical Interpretation

F. F. REYNOLDS
Geophysicist
Seismic Explorations, Inc.
Gulf Building Houston, Texas

ROBERT H. RAY
ROBERT H. RAY, INC.
Geophysical Engineering
Gravity Surveys and Interpretation
Gulf Bldg. Houston, Tex.

L. M. MOTT-SMITH
Mott-Smith Corporation
Gravimeter Surveys and Equipment
909 Shell Building
HOUSTON, TEXAS

Please mention GEOPHYSICS when answering advertisers

A Special Film for a Special Purpose

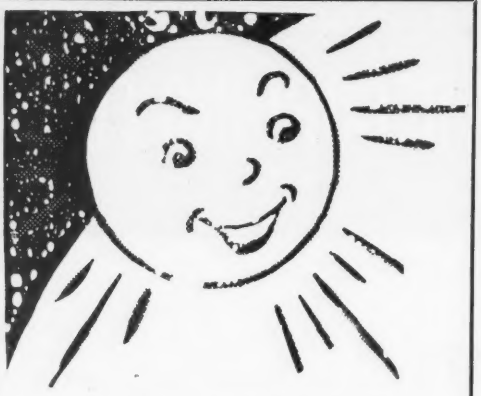
EASTMAN SURVEY RECORDING FILM

- ***ADEQUATE SPEED***
- ***HIGH CONTRAST***
- ***FINE GRAIN***
- ***ANTIHALATION***
- ***PHYSICAL HARDNESS***

EASTMAN Survey Recording Film, safety base, is a special product, developed to meet highly specialized requirements. This film is characterized by high contrast, high resolving power, speed, and antihalation qualities to enable it to record the fastest oscillograph traces. These photographic qualities are coupled with extreme physical hardness and resistance to heat so that it can be handled satisfactorily and easily under the most severe field conditions. It is spooled and packed to meet the customer's needs.

IF YOU HAVE A RECORDING PROBLEM
WE SHALL GLADLY HELP YOU SOLVE IT—
JUST WRITE US

EASTMAN KODAK COMPANY, ROCHESTER, N. Y.



ALL CLEAR

with NELSON-backed WIRE, CORDS, & CABLES for seismograph work. Call NELSON'S for batteries, Weston instruments.

NELSON
Electric Supply Company
DALLAS TULSA

THE GEOTECHNICAL CORPORATION

ROLAND F. BEERS
President

1702 Tower Petroleum Building
Dallas, Texas
Telephone L D 711

Save costly down time

with LANE-WELLS Combination Electrolog-Survey Service!

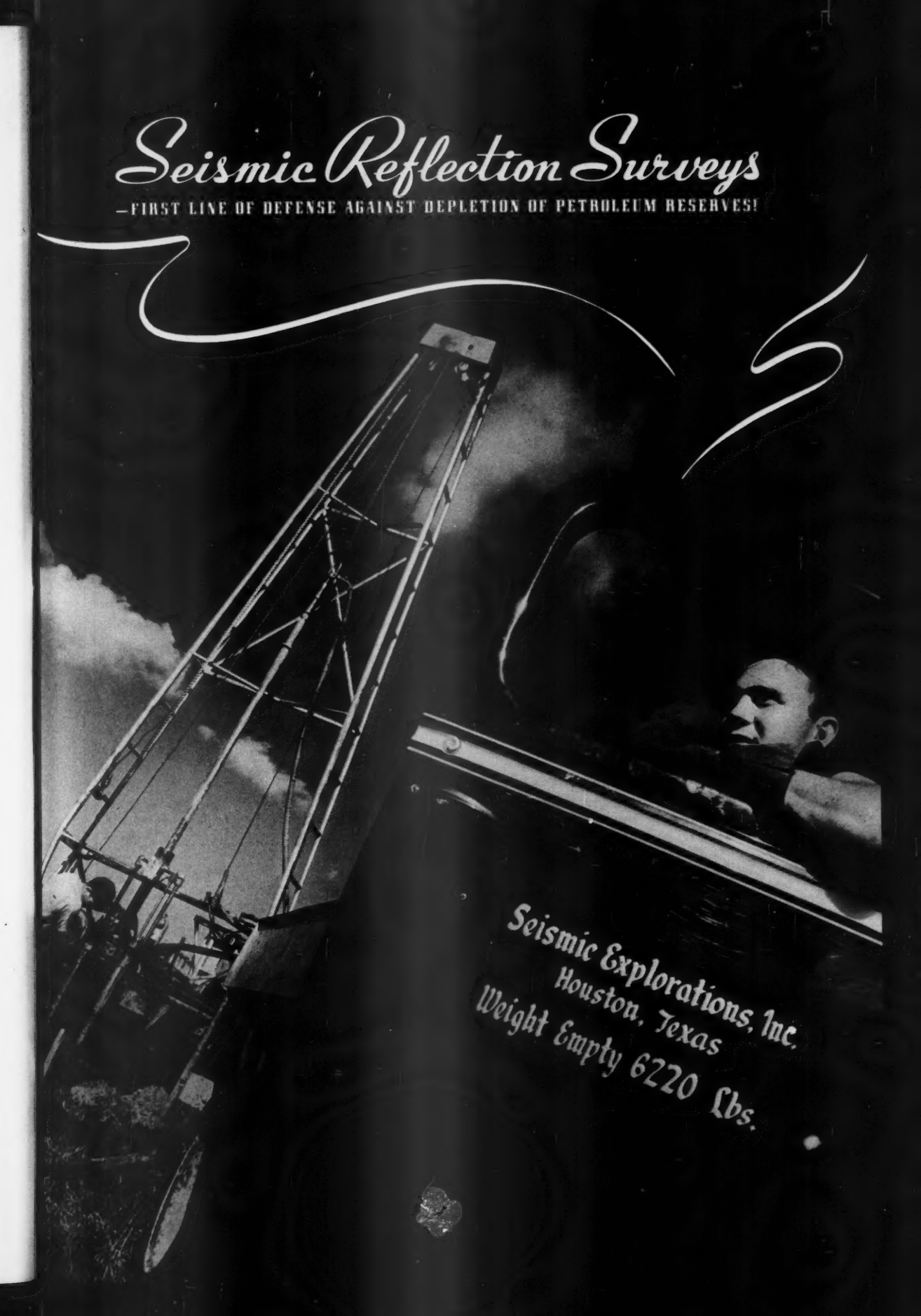
Save from two to two and one-half hours in crew time by using Lane-Wells COMBINATION Electrolog-SURVEY SERVICE.

An Electrolog run is made first to record accurately and in detail formation resistivities and natural potentials. A Multiple Shot Survey Instrument is then attached to the electrode and run to the bottom of the hole. Hole inclination and direction are recorded magnetically on the film as the survey instrument is withdrawn from the bottom of the hole. Lane-Wells measuring devices assure positive accuracy of both runs.

If crew time is a factor in your drilling costs—call Lane-Wells and ask about this "down time saving."

LANE-WELLS EVERYWHERE

ELECTRICAL OPEN HOLE LOGGING · OIL WELL SURVEYING · GUN PERFORATING · PACKERS · LINER HANGERS · BRIDGING PLUGS


Seismic Reflection Surveys
—FIRST LINE OF DEFENSE AGAINST DEPLETION OF PETROLEUM RESERVES!
Seismic Explorations, Inc.
Houston, Texas
Weight Empty 6220 Lbs.

SPECIAL PUBLICATIONS

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Box 979, Tulsa, Oklahoma

1935 **Geology of Natural Gas.** Symposium on occurrence and geology of natural gas in North America. By many authors. 1,227 pp., 250 illus. 6 x 9 inches. Cloth. **To members and associates, $4.50** ..... $ 6.00

1936 **Geology of the Tampico Region, Mexico.** By John M. Muir. 280 pp., 15 half-tone plates, 41 line drawings, 9 tables. 6 x 9 inches. Cloth. **To members and associates, $3.50** 4.50

1936 **Gulf Coast Oil Fields.** Symposium on Gulf Coast Cenozoic. By 52 authors. Chiefly papers reprinted from the Association *Bulletin* of 1933-1936 gathered into one book. xxii and 1,070 pp., 292 figs., 19 half-tone pls. 6 x 9 inches. Cloth. **To members and associates, $3.00** 4.00

1936 **Areal and Tectonic Map of Southern California.** By R. D. Reed and J. S. Hollister. In 10 colors. From "Structural Evolution of Southern California," December, 1936, *Bulletin*. Scale, ⅛ inch = 1 mile. Map and 4 structure sections on strong ledger paper, 27 x 31 inches, rolled in mailing tube. ..... .50

1937 **Comprehensive Index** of 20 volumes of the *Bulletin* and all special publications of the Association (1917-1936). By Daisy Winifred Heath. 382 pp., 6.75 x 9.5 inches. Paper. **To paid up members and associates, one copy free** 3.00

1938 **Miocene Stratigraphy of California.** By Robert M. Kleinpell. 450 pp., 14 line drawings, including a large correlation chart. 22 full-tone plates of foraminifera; 18 tables (check lists and a range chart of 15 pages). 6 x 9 inches. Cloth. **To members and associates, $4.50** 5.00

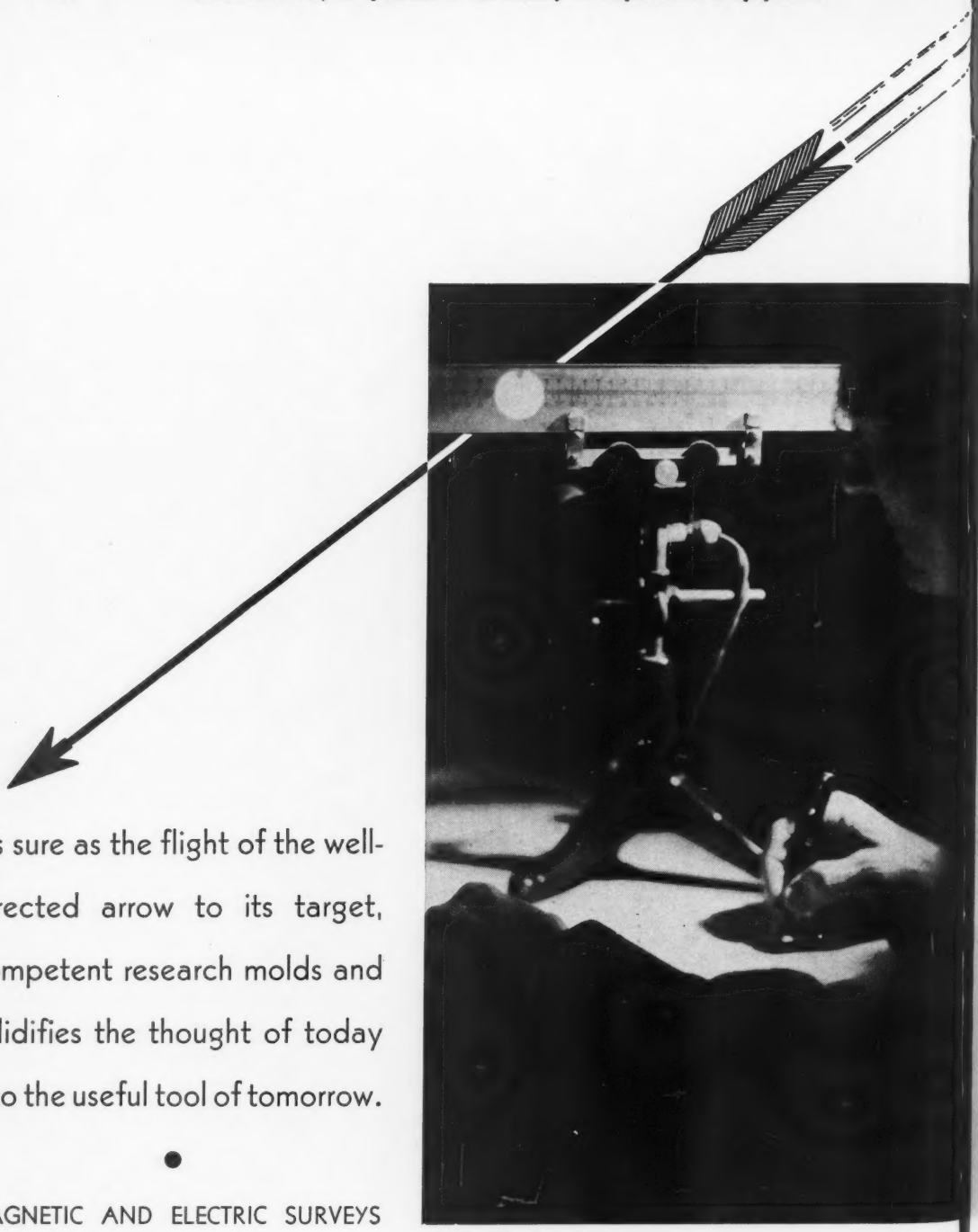
1939 **Recent Marine Sediments.** Symposium of 34 papers by 31 authors. Collected by the committee on sedimentation, Division of Geology and Geography, National Research Council. 736 pp., 139 figs. 6 x 9 inches. Cloth. **To members and associates, $4.00** 5.00

Prices postpaid. Write for discount to colleges and public libraries.

In Oklahoma, add 2 per cent for sales tax.

For Reliable Subsurface Data Backed by Years of Experience, Call Schlumberger, the Pioneer!

SCHLUMBERGER WELL SURVEYING CORPORATION · HOUSTON, TEXAS



As sure as the flight of the well-directed arrow to its target, competent research molds and solidifies the thought of today into the useful tool of tomorrow.

•

MAGNETIC AND ELECTRIC SURVEYS

WILLIAM M. BARRET, INC.

Consulting Geophysicists

GIDDENS-LANE BLDG., SHREVEPORT, LA.

A New Book of Unusual Interest

GEOPHYSICAL PROSPECTING FOR OIL

By L. L. NETTLETON

Geophysicist, Gulf Research & Development Company
Advisory Professor of Physics, University of Pittsburgh

444 pages, 6 x 9, illustrated. $5.00

The purpose of this important new book is to provide in a single volume a connected presentation of the principles and practice of modern oil prospecting by geophysical methods. The selection and emphasis of subject matter have been governed by the author's wide experience and active participation in the application of geophysical methods to prospecting through most of the period of their development. Particular care has been taken to explain clearly the necessary procedures for reducing field measurements to usable form.

Send for a copy on approval

McGRAW-HILL BOOK COMPANY, Inc.

330 West 42nd Street **New York, N.Y.**

Applied Physics
is never a static science.

Research done today is extended and refined tomorrow.

Through the medium of a periodical, developments can be presented as they come from the laboratories.

THE JOURNAL OF APPLIED PHYSICS

has published special articles on

X-rays, Television, Photography, Spectroscopy, Photoelasticity.
Other special issues are planned

THE JOURNAL OF APPLIED PHYSICS
offers the following subscription price:

	U.S., Poss. and Canada	Foreign
To members of scientific societies	$5.00	$5.70
To all others	7.00	7.70

Address subscriptions to

The American Institute of Physics
175 Fifth Avenue, New York, New York

This Changing World

Month by month the panorama of world oil activity changes. Month by month important new developments are taking place. New concessions, new alignments in the politico-economic maze of world oil diplomacy are forming. New areas are being opened to exploration. New discoveries are recorded. New pipe lines and refineries are being planned at strategic locations on the world map. Never before have the operations of the world's most dynamic industry covered so broad a field or attained such intensive activity.

Within the past few years the oil industry has entered a new era. Today it is more important and more difficult than ever before to keep informed of what is happening, not only at home but in every part of the world. Keep posted on what is taking place and what it portends. To do this become a regular reader of WORLD PETROLEUM, the international organ of the oil industry.

WORLD PETROLEUM presents each month a picture of important developments in the world of oil. It deals with economic, political and commercial aspects of the industry and interprets the significance of events that it records. No oil man who desires to be well informed will be satisfied to be without it.

WORLD PETROLEUM is the magazine of today and tomorrow. It is read by men of present responsibility and by those who expect to assume responsible positions; by all who want to keep pace with a rapidly growing, swiftly changing industry of worldwide perspective and dimensions.

WORLD PETROLEUM

A Year's Subscription

$5.00	£1-1
95 River St.	3 Savoy Place
Hoboken, N.J.	London, W.C.2

Please mention GEOPHYSICS when answering advertisers

Successful GEOPHYSICAL SERVICE FOR THE AMERICAS

The wide experience gained by UNITED'S field crews in both North and South America is a valuable asset to seismic exploration programs.

Backed by continuous research . . . constant improvement of existing methods . . . and the use of every modern facility for scientific prospecting, UNITED'S thoroughly trained organization has established an outstanding record for successful geophysical surveys.

Complete Information Will Be Sent On Request

UNITED GEOPHYSICAL CO.

HERBERT HOOVER JR., [illegible].

1235 East Green Street, Pasade[illegible], California
2406 Esperson Building, Ho[illegible]on, Texas
420 Lexington Ave., New York C[illegible], New York
Edificio Odeon, Sala 1018 Rio de J[illegible]iro, Brazil

J. P. SCHUMACHER W. G. SAVILLE A. C. PAGAN

GRAVITY METER EXPLORATION COMPANY
and
TORSION BALANCE EXPLORATION COMPANY
Established 1925

830-32 Shell Bldg.
HOUSTON, TEXAS

Phone: Cap. 9018
Cable: Torbalex

HANS LUNDBERG LIMITED

NEW YORK, 26 Beaver St.
TORONTO, Victory Building
VANCOUVER, Marine Building

Hans Lundberg
Theodor Zuschlag
Douglas Burton
R. Grimes-Graeme, Ph.D.
G. K. Lowther, Ph.D.
Basil T. Wilson, M.Sc.

GEOLOGICAL AND GEOPHYSICAL SURVEYS
Electrical, Magnetic, Gravimetric, Seismic, Radioactive and Spectrographic Methods

A cumulative index of Society publications from 1931 through 1939 was mailed out with the July issue of *Geophysics*, Volume V, Number 3. Those who failed to obtain a copy may secure one by addressing

The Society of Exploration Geophysicists
P.O. Box 777 **Austin, Texas**

The Annotated Bibliography of Economic Geology, Vol. XII No. 2

No. 1 of Volume XII of the Annotated Bibliography was issued in April. No. 2 will appear Oct. 10th.

Price $5.00 per year of two numbers.

The Index of the first 10 volumes contains 496 pages and over 50,000 entries.

Price $5.00

Address: **Economic Geology Publishing Company**
Urbana, Illinois

What do you want in a GEOPHYSICAL SERVICE?

RESEARCH?

EQUIPMENT?

EXPERIENCE?

ACHIEVEMENT?

WESTERN GEOPHYSICAL COMPANY maintains the most modernly-equipped and complete geophysical research laboratory of its kind *in the world,* employing 42 trained technicians.

WESTERN designs and manufactures in its own shops all types of geophysical instruments and equipment, including both large and small drilling units, used by its field crews.

WESTERN draws from the combined experience of twenty active field crews, engaged in geophysical exploration in diverse localities, who are solving all types of geophysical problems.

WESTERN is proud of the many oil fields which it has discovered for its clients in both California and Mid-Continent areas. It feels, however, that credit for these discoveries should be given to the excellent geological staffs of its clients under whose direction the various crews operated. It claims sole credit, however, for the accuracy of its results which are attested by every one of its clients without exception.

Because WESTERN GEOPHYSICAL COMPANY has complete research facilities...equipment...experience...personnel... and has an outstanding record for successful results, it meets every requirement of operators desiring a *complete* and highly advanced geophysical service. ☆ Trained and experienced field crews are available for geophysical prospecting anywhere in the United States or abroad. Your inquiries invited.

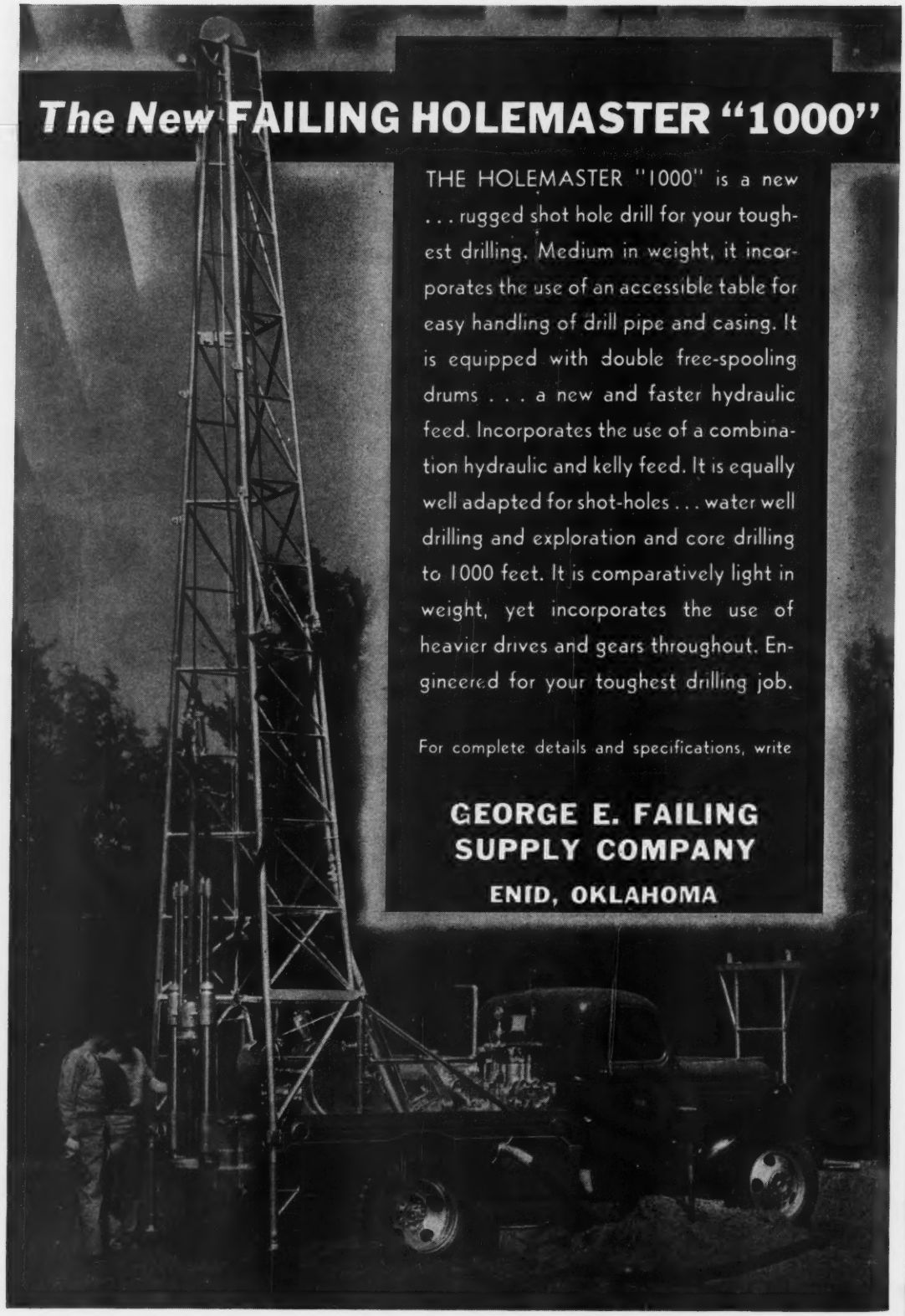
WESTERN GEOPHYSICAL COMPANY

HENRY SALVATORI, PRESIDENT

MAIN OFFICE; EDISON BLDG., LOS ANGELES, CALIF.

MID-CONTINENT OFFICE; PHILCADE BLDG., TULSA, OKLA.

CABLE ADDRESS "WESGECO"


The New FAILING HOLEMASTER "1000"
THE HOLEMASTER "1000" is a new . . . rugged shot hole drill for your toughest drilling. Medium in weight, it incorporates the use of an accessible table for easy handling of drill pipe and casing. It is equipped with double free-spooling drums . . . a new and faster hydraulic feed. Incorporates the use of a combination hydraulic and kelly feed. It is equally well adapted for shot-holes . . . water well drilling and exploration and core drilling to 1000 feet. It is comparatively light in weight, yet incorporates the use of heavier drives and gears throughout. Engineered for your toughest drilling job.
For complete details and specifications, write
GEORGE E. FAILING SUPPLY COMPANY
ENID, OKLAHOMA

The World Knows!

For the past ten years oil companies, the world over, have called upon *S S C* to help in their exploration problems. The continued growth of *S S C* indicates clearly that successful results must have been obtained.

S S C's trained and carefully supervised crews are always available for any type of seismic exploration anywhere in the world.

World Wide Experience

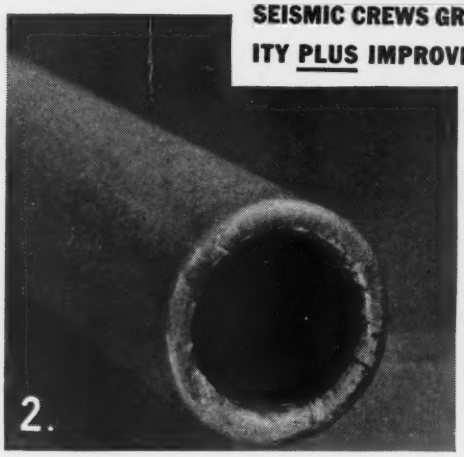
Seismograph Service Corporation

CONSULTING EXPLORATION GEOPHYSICISTS

KENNEDY BUILDING

TULSA, OKLAHOMA, U. S. A.

NEW CONVOLUTE TUBE CARTRIDGE OFFERS SEISMIC CREWS GREATER CARTRIDGE RIGIDITY PLUS IMPROVED GELATIN PLASTICITY



1. *2-in. x 2½-lb. cartridge of Seismogel 60% cartridged in convolute tube.* 2. 3. *Note the smooth ends which permit efficient splicing of cartridges and are adequately strong to withstand excessive pressures from a loading stick.*

2 MORE ADVANTAGES IN DU PONT SEISMOGRAPH EXPLOSIVES

HERE'S an improvement in packaging explosives that offers double advantages to seismic prospecting crews.

The new convolute tube cartridge, now standard on Du Pont Seismogel and Du Pont Seismograph 60% Hi-Velocity Gelatin, makes each cartridge far firmer—able to stand much more abuse. Loading units made up of these new, stiff cartridges are more rigid. They can stand much more pressure without buckling when shoved through heavy muck.

At the same time, this increased cartridge rigidity permits greater gelatin plasticity. This increased plasticity makes it more convenient to handle segments of cartridges.

And, as always, Du Pont Seismograph Explosives offer you the utmost in efficiency. They detonate at high velocity . . . and they attain their maximum velocity in minimum time.

E. I. DU PONT DE NEMOURS & CO. (INC.), EXPLOSIVES DEPT., WILMINGTON, DELAWARE

DU PONT **EXPLOSIVES** *and* **BLASTING ACCESSORIES**

Let us Review Your Records on the Basis of our Record

call in G.S.I.

With a G.S.I. review, areas surveyed and condemned may be made to 'live again,' in the light of new interpretations . . . producing realities may develop from filed possibilities.

Our record review department operates with the same advanced technique and knowledge that has established G.S.I.'s leadership. This leadership is based on the prediction of 137 producing fields throughout the world. The greatest number of successes attributed to any consulting company, by more than two for one.

Review Service is not confined solely to rechecking old surveys.

It is also available for checking current records and maps presented by other companies. The reasonable service cost is negligible when compared to the thousands that may be made or saved . . . whatever the answer.

Write today for information on G.S.I.'s Record Review Service.

GEOPHYSICAL SERVICE INC.

EUGENE McDERMOTT, President

SEISMOGRAPH SURVEYS
SOIL SURVEYS

Branch Offices: Houston, Texas - Jackson, Miss.
Los Angeles, Calif. • Tulsa, Okla.

DALLAS, TEXAS

Please mention GEOPHYSICS when answering advertisers

Through an Agreement in the field of

GEOCHEMICAL PROSPECTING FOR PETROLEUM

by

SOIL ANALYSIS, SOIL GAS ANALYSIS, AND GEOCHEMICAL WELL LOGGING,

Licenses, under the pertinent Patents and Patent Applications, in the U.S.A. and Foreign Countries of

SUBTERREX

and

STANDARD OIL DEVELOPMENT COMPANY

are available, exclusively, through

E. E. ROSAIRE.

Issued Patents include, but are not confined to, the following

U. S. Patents	Foreign Patents	
1,843,878	Iran	457
2,112,845	Venezuela	1815
2,170,435	Brazil	24,749
2,177,139	New Zealand	81,168
2,183,964	Australia	105,418
2,192,525	Canada	367,692
2,198,619	England	504,617

The following organizations are now licensed under this Agreement:

Standard Oil Company of New Jersey
New York, N.Y.

Humble Oil and Refining Company
Houston, Texas

Carter Oil Company
Tulsa, Oklahoma

Subterrex
Houston, Texas

Geophysical Service, Inc.
Dallas, Texas

Geochemical Service Corp.
Tulsa, Oklahoma

Correspondence Is Invited, and Should be Addressed to

Subterrex

701 Waugh Drive, Houston, Texas